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HOUSE AT CANTON, ILL.

R. C. Spencer, Jr., Architect, Chicago, Ill.

Paving Brick Walls; Stud Frame Above, Plaster on Metal Lath, Paneled by Undressed and Stained Boards; Red Shingle Tile Roof.

Carpentry *and* Contracting

A Practical Reference Work on

CARPENTRY, BUILDING SUPERINTENDENCE, CONTRACTING, SPECIFICATIONS, ESTIMATING, BUILDING LAWS AND CODE, UNDERWRITERS' REQUIREMENTS, HEATING, VENTILATION, PIPE FITTING, PLUMBING, ARCHITECTURAL DRAWING, BLUEPRINT READING, ETC.

Prepared by a Staff of

ARCHITECTS, CARPENTERS, CONTRACTORS, AND BUILDING EXPERTS OF THE HIGHEST PROFESSIONAL STANDING

Illustrated with over Fifteen Hundred Illustrations

FIVE VOLUMES

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Grateful acknowledgment is here made also for the invaluable cooperation of the foremost architects, engineers, and builders in making these volumes thoroughly representative of the very best and latest practice in the design and construction of buildings; also for valuable drawings and data, suggestions, criticisms, and other courtesies.

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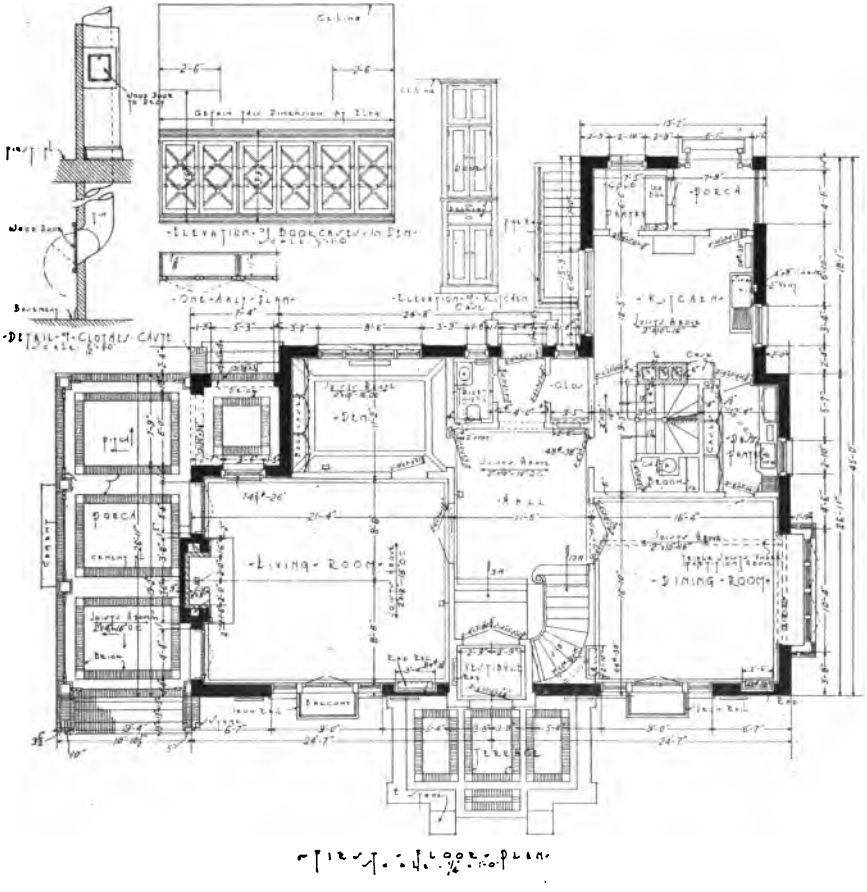
Ceiling
Wood Beam
Basement
Detail of Closet Cave
Elevation of Bookcase
One Half Plan
Elevation of Kitchen Cabinet
Porch
Kitchen
Glass
Hall
Living Room
Dining Room
Bedroom
Bedroom
Bedroom
Balcony
Terrace
Porch
Porch
Cement
Cement
Cement

RESIDENCE OF CLIFFORD OFF AT PEORIA, ILLINOIS

Hewitt and Emerson, Architects, Peoria, Illinois

A rather interesting example of a symmetrical exterior fitted to an unsymmetrical plan. The house is of brick veneer construction with a slate roof. Cost about $14,000. For floor plans see reverse side of page.

Foreword

THE building industry is today one of our most important and permanent institutions. Every new family unit must find a dwelling place, every new industry must be properly housed in order to do its work without hindrance from the weather. But with this development have come complications never dreamed of by our forefathers. In former years, every carpenter was a builder and he did very well for he confined himself to simple jobs—in fact there were none but simple jobs. There were then no complications with plumbing, gas and water fitting, heating, electric wiring, etc. There were no city ordinances to comply with, no building restrictions to be acquainted with. The laws regarding property rights, labor, etc., were simple, and the question of material was not as complicated.

¶ Today, however, all these things must be considered even if a building is to be erected in a comparatively small town. Most villages have some kind of water system, electricity and gas are almost everywhere, and the house builder demands more artistry in the design and more comforts within the home. Year by year, the practices of our best builders are becoming more standardized, more refined, and more practical. New methods, new tools, and labor-saving ideas are being evolved as new problems of construction present themselves. It therefore behooves every contractor and builder to keep in touch with the progress of the art by possessing handbooks and reference works which will show him the way.

¶ In the preparation of these volumes, the aim has been to create not merely a work which will appeal to the trained expert but one that will commend itself to the beginner and to the self-taught practical man by broadening his knowledge beyond the limits of his experience.

¶ Another point which has been considered is that, notwithstanding the fact that this is a day of specialists, every contractor and builder must be familiar with the specifications for the foundations, framing, interior work, heating, plumbing, wiring, and other specialties entering into the construction of the building. This information is presented in readable form and will be found adequate for the construction of buildings of moderate size. For the details of construction of large buildings of steel and concrete, readers are referred to our more comprehensive reference work entitled "Architecture, Carpentry, and Building" in ten volumes.

¶ The various sections of this work have been prepared especially for home study by acknowledged experts on the subjects and are as free from technical terms as possible. The importance of such practical subjects as Carpentry, Building Superintendence, Estimating, Steam and Hot-Water Fitting, Drainage and Venting, Blueprint Reading, etc., has been emphasized. The illustrations have been selected with care, and numerous tables and diagrams are introduced wherever possible. It is the hope of the publishers that this reference work will be found of distinct value in its field.

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"COURT OF THE OAKS" AT PASADENA, CALIFORNIA
George A. Clark, Designer, Pasadena, California
This pleasing group consists of six semi-detached apartments

BUILDING SUPERINTENDENCE

PART I

FRAME CONSTRUCTION

INTRODUCTION

Responsibilities of Superintendent. The superintendence of building operations is one of the most important and, at times, one of the most perplexing duties which an architect is called upon to perform. Plans may have been prepared with the greatest of skill and elaboration, and details may have been worked out to a marvel of perfection; and yet by the want of attention given at the proper time, costly mistakes may be made and results attained which are a source of annoyance and expense to the owner, and often a lasting discredit to both architect and builder. It is only by constant watchfulness and by the exercise of a thorough knowledge of common practices and materials, that these errors can be avoided, and it is the duty of the architect, as superintendent, and as a just and impartial referee between the owner and the builder, to acquire this knowledge and to exercise it freely and decisively.

The owner, who has secured the services of an architect, will naturally expect from him something more than the builder could have furnished. Superiority in matters of taste he will look for as a matter of course, and, beyond this, a superior knowledge of materials and construction, and an executive ability to handle men and direct the many forces which must be applied to obtain a certain and satisfactory result. The architect should possess then, as superintendent, a thorough knowledge of the materials at his disposal and should see clearly before him, with his mind's eye, the building which he proposes to erect. To do this, he must know how all the various elements of the building are to be assembled and molded into a complete whole.

To a familiarity with details, the architect must add such a quickness of perception and soundness of judgment, that it will be impossible for any bad work to escape his notice; and to this

knowledge of the general principles of building, he must add an understanding of principles and possibilities far beyond that of the builder, so that he can foresee causes and effects and guard against any waste of effort or of time. In his position of referee, he must show such a familiarity with building matters that his judgment will be respected by both owner and builder, and he must have confidence that his opinions are correct. Having rendered a decision, he must stick to it, for any weakness or indecision will be quickly discovered by the workmen, and the architect will be discredited and very likely imposed upon. It will not do for him to trust too much to the generosity of the owner, or to the liberal intentions of the builder, for it is probable that both are at the same time trusting in the ability of the architect and the clearness of his foresight.

The preliminary remarks here made upon the duties and responsibilities of the superintendent will serve to bring before the student of architecture the importance of familiarity with ordinary practice. The young architect or student will rarely have an opportunity of gaining this knowledge by practical experience, and it will be necessary for him to depend in a great measure upon technical books for information he must possess. It will be the object of this paper to point out to the student, in a manner that can be easily understood, some of the ordinary methods of building construction, rather than the theoretically perfect methods, and to show as well some of the ways in which defective work and materials are to be discovered and avoided.

It will be assumed that the student has become familiar with the usual methods of drawing and construction from his previous work, and that he would be able, if called upon, to superintend the construction of the suburban house which is here used as a type. This does not mean that the erection of a dwelling is the easiest matter, for such is not the case; but this class of building has been chosen because there is greater opportunity for the comparison of results with practice—with the buildings in which we live—and also because it contains a variety of structural problems.

Relations with Owner and Contractor. It is important for the architect to have, as early as possible, a clear understanding of what is expected by the owner, and for the owner to have an equally clear understanding of what is due to him from the archi-

tect. The owner, in his implicit confidence and trust in the foresight of the architect, is likely to visit upon him the blame for particular failures of construction which could only be avoided by the care of superior workmen under the constant watchfulness of the builder or an ever-alert clerk of the works; and it is well for the architect to have it understood at the beginning that he cannot always be present and that he cannot in ordinary practice guarantee perfection of plan or execution, but that he will agree to give reasonable care and observation.

With the contractor it should be clearly understood at the beginning that the work is to be done strictly in accordance with the drawings and specifications, that the materials are to be as called for, the workmen to be competent, and the builder himself interested and capable. If any unfit material appears upon the site, it should be rejected at once and finally, for any laxity or indecision upon this point at the start will surely be taken advantage of, and will be a precedent for future indifference. Any work not done carefully or in accordance with the drawings, must be at once taken down, in the presence of the architect if possible, and any mistakes discovered should be noted before they are forgotten or crowded aside by other details.

With the foreman an understanding should be had at once that he is to work *with* the architect and not *against* him. It is poor policy for the architect to ignore suggestions made by the foreman, for if the latter is a thorough mechanic of ability and foresight, as the foreman of a building of any importance should be, he will often be in a position to save the owner from needless expense, and the architect from many of the vexatious conditions and minor complications which frequently arise in ordinary building transactions.

Familiarity with Site. Of prime importance to the architect in starting a new building is a familiarity with the site and with local conditions and customs; it will also be of advantage to him to make the greatest possible use of the time spent in preliminary visits to the locality, to observe what is being or has been done in the vicinity. The more familiar the architect is with local customs or possibilities, the more efficient will his supervision of that particular building become, through the rejection of practices which are bad and the adoption of those which are good. There are very

few buildings from which the young architect cannot learn something, and it is an unprogressive builder who has not some particular method which will be new to the superintendent.

Familiarity with Drawings. Another essential, a matter of the greatest importance, is that the superintendent should have a perfect understanding of the drawings and specifications. If these have been prepared by the architect who is to superintend the work, an understanding is assured, but even in this case it will be necessary to consult the plans often, lest something be overlooked or confused with some other building which the architect may have in mind. Familiarity with the plans and specifications will also be of service in enabling him to look ahead, and to prevent many unintentional deviations which carelessness or lack of understanding on the part of the builder, or of the foreman upon whom will devolve many of the duties and responsibilities of modern building operations, might occasion, and which, once started, might seriously delay or damage the construction. The foreman, and the master builder himself, as well, should receive personal directions from the architect, and should be particularly instructed to look over the drawings carefully, and to report to the architect any discrepancies in figuring or any apparent difficulties of execution which either may discover, and all points not clearly shown or fully understood.

Self-Confidence. With this feeling of co-operation thoroughly established between the owner, the architect, and the builder, the architect will be in a position to decide any questions of difference with an assurance that his decisions, being fair and impartial, will be respected. Satisfied that his opinions are correct, he should announce his decisions promptly and impartially, and, his answer being once given, he must have the courage to maintain his position until proved to be in the wrong. Hesitation or a lack of confidence in his own judgment might affect the prestige of the architect, and might be taken advantage of.

Systematic Plan of Supervision. In following the construction of a building, the superintendent will find it of importance to adopt some systematic method in order to make sure that attention is given to the various details of construction at the proper time. If this is not done, many defects of construction and workmanship are likely to be concealed or built upon in such a way as to make

correction impossible, or at the least inconvenient. To prevent this, the superintendent should make a point of going all over the building at each visit and examining carefully any work which has been done since his last visit. In this way he will not only guard against concealed defects but he will be able to time his next visit so that special operations, which he will be able to foresee, will receive his personal attention and direction at the proper time.

Inspection of Materials. One of the most important safeguards against defective building is the careful inspection of the materials as they are delivered at the building site, and the prompt rejection of any improper materials. These should be marked plainly, in such a way that it will be impossible to use them in the superintendent's absence without the mark being seen. If poor materials have been brought into the building, they should be rejected at once and, if possible, removed from the building site. If the contractor finds at the start that all poor materials will surely be rejected and that all work which is not properly done must surely be rebuilt, he will be careful that both workmanship and materials are maintained at the proper standard and, for his own sake as well as for the good of the building, he will keep on the building only workmen who prefer to do a good job rather than a bad one.

PRELIMINARY CONSIDERATIONS

Selection of Site. First in importance to the owner as well as to the architect is the selection of the spot where the house is to stand. To the owner the essentials will be the outlook and ease of access, and, at the same time, the appearance which the house will present from the various approaches, and the light and warmth of sunshine possible in the principal rooms. In almost all portions of our country a southern or eastern exposure is the pleasantest and should be the choice for the main rooms, that they may thus receive the morning sunshine and warmth in winter and avoid the intense heat of the afternoon in summer.

To the architect, less apparent but no less essential considerations present themselves in the practical aspects of the ground. In rocky or hilly country, besides the significance of the outlook, is the importance of placing the house so that natural advantages of slope and ledge may be profited by for driveways and yards.

Study of Soil. In every location the consideration of the character of the soil is of great moment. It may be rocky, or clayey, or sandy; it may be springy or well drained. The surest way to find out the actual condition is by digging test pits to the proposed depth of the cellar, but in many cases the appearance of the surface will give sufficient indication of the nature of the soil, while the presence of ledge may be detected by driving a rod into the ground to the depth of excavation. If the soil is rocky or clayey, we may anticipate trouble from water, which in rock or clay finds a way into the excavations, Fig. 1, and, having no way of escape, gradually rises until the pressure is sufficient to force a way through the cellar wall or concrete, in spite of almost any precaution which may be taken to exclude it. The only remedy is to give the water an easier way to escape than through the wall or cellar concreting; in towns where there are sewers this is an easy matter, as it is only necessary to secure a good connection with the sewer by means of suitable pipes, which must be started at a level lower than the cellar bottom, Fig. 2. This makes it necessary for the house to be set high enough so that the bottom of the cellar is well above the top of the sewer. If the house is in a locality where there is no sewer, water may be guarded against similarly by laying drains with a proper grade from the cellar of the house to an outlet wherever one can be found at a lower level. This can usually be done in a rolling country; but a cellar in clay

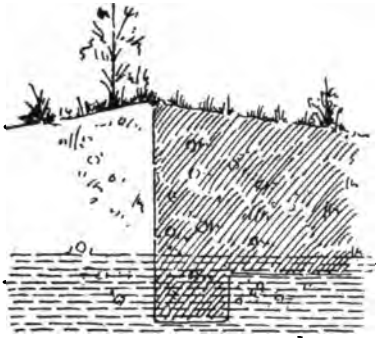


Fig. 1. Ground Water in Soil Excavation

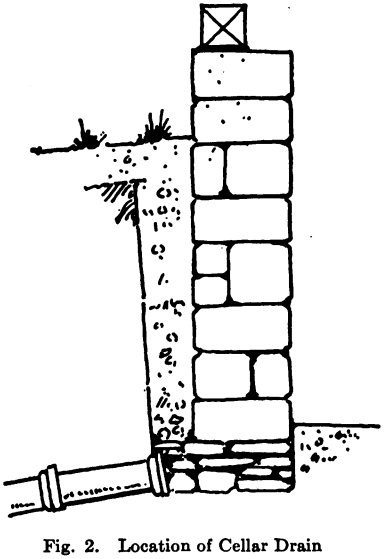


Fig. 2. Location of Cellar Drain

or rock in a level country is likely to be a continual source of trouble and should be avoided if possible. Most suburban towns afford some choice in house lots, so that often serious trouble may be evaded by a careful examination of the soil and of surrounding conditions before purchase is finally made. In sandy or gravelly soil hardly any extra precautions will be needed as the water is free to drain away through the sand and will have no tendency to run through the wall of the cellar. Even in sandy soil, however, it will be well to give the outside of the wall a coating of cement or asphaltum, care being taken to see that the whole surface is covered.

Description of House. The house which we will assume to construct is the same as that treated in detail in "Architectural Drawing", and we may suppose it to be erected upon a suburban lot not wholly level but with the usual variations of ground and aspect. The house is designed in the colonial style, Fig. 3, and comprises a large living-room, hall, parlor, dining-room, back hall, china closet, kitchen, pantry, and entry, on the first floor, Fig. 4; and five chambers with bathroom and stair halls on the second floor, Fig. 5. The attic is unfinished, and the basement contains a laundry with wash trays, a storeroom, and servant's water closet.

The living-room is finished in quartered oak, the dining-room in mahogany, the parlor, halls, and sleeping-rooms in white painted finish. The kitchen and service portions of the house are finished in North Carolina hard pine. The floors of the main house are of quartered oak in the first story and spruce in the second story; the floors of the service portions are of Georgia pine. The exterior walls are clapboarded and the roof shingled.

Drawings. The drawings upon which the contracts are to be based consist of a plan of each floor, a roof plan, and elevations of all four sides. Where the inside finish is at all elaborate, sectional drawings are made in sufficient number to show all of the rooms and halls. These general drawings, supplemented later by framing drawings and details and a carefully written set of specifications, represent the labor, materials, and methods to be employed. The necessity for a perfect familiarity with these drawings and specifications on the part of the superintendent is obvious, and has been already dwelt upon to some length, but a few words may well be

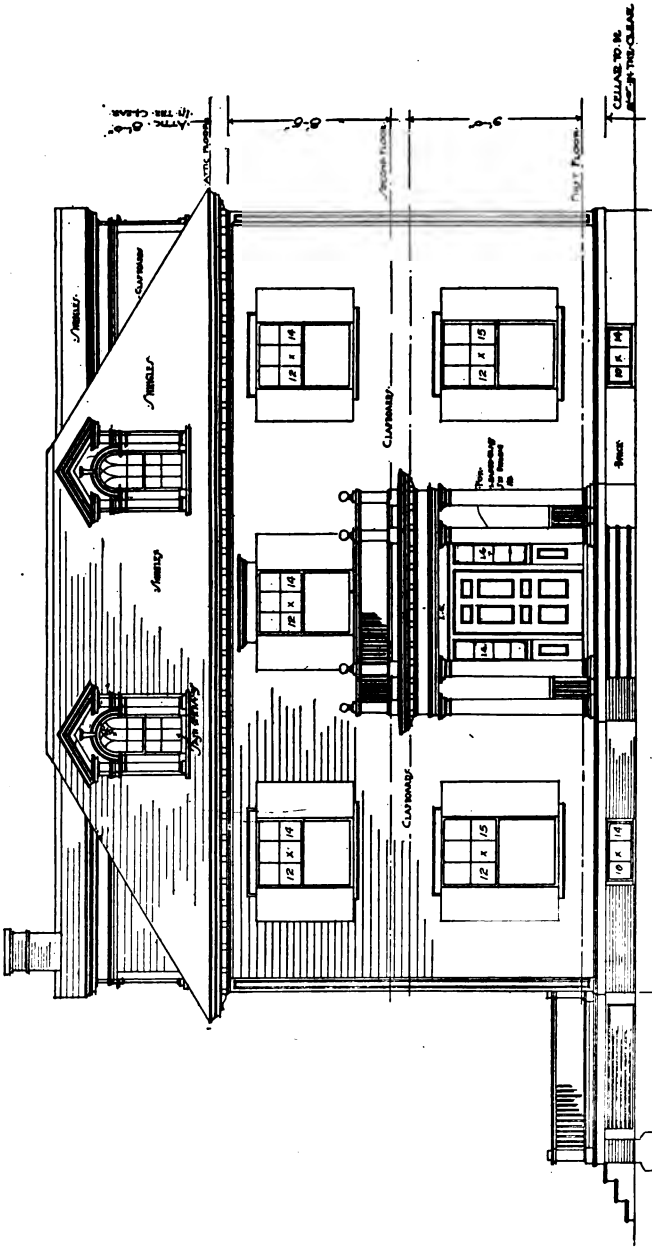
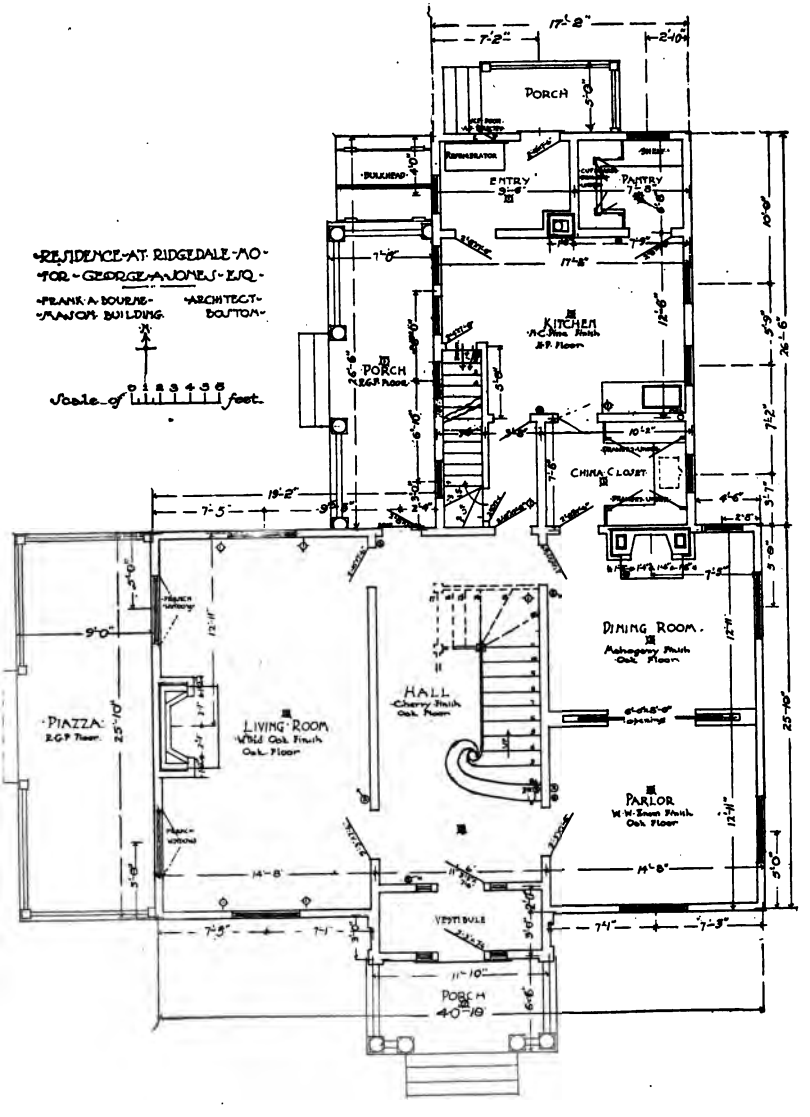


Fig. 3. Residence under Consideration, Designed for George A. Jones, Ridgedale, Missouri
Courtesy of Frank A. Bourne, Architect, Boston, Massachusetts



PLAN OF FIRST FLOOR

Fig. 4. Plan of First Floor of the Jones Residence

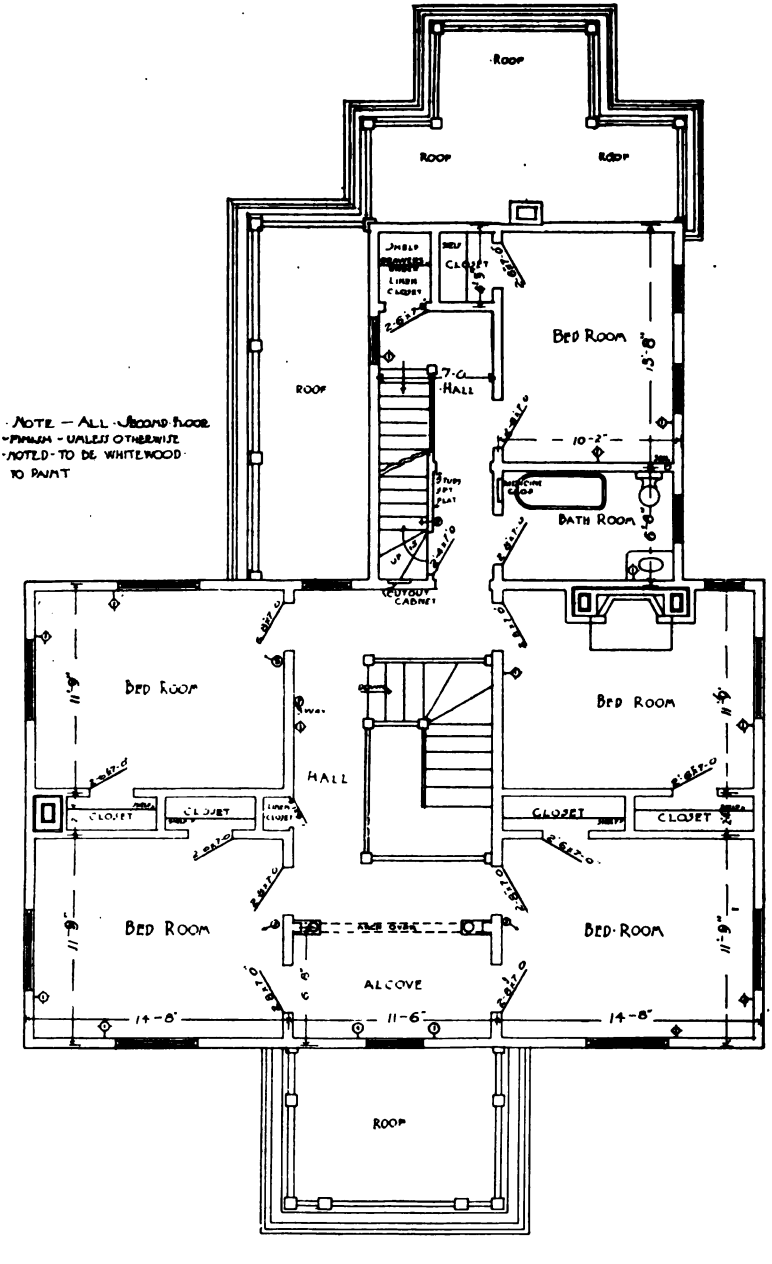


Fig. 5. Plan of Second Floor of the Jones Residence

given here with regard to the same precautions on the part of the owner and of the contractor.

Study of Plans and Specifications of Value to Owner. It will be to the interest of the owner, if he will take the time and trouble while the drawings are yet being made, to consider, with the help of the architect, the various details of construction and furnishing, and to become familiar with the drawings, that he may clearly understand just what they are intended to represent. By comparing sizes of rooms, doors, stairs, and other fixtures, as drawn, with houses already built, he will be able to satisfy himself that the house, when finished, will be according to his wish. The specifications may to good advantage be examined at home, that he may receive suggestions from the various members of his family, and modifications can then be readily made to meet individual preferences and tastes. Careful study of this kind will be of great value to the owner, and will often avoid later expense in altering work which, in the absence of particular instruction, would have been carried out in the usual way; and the architect will find that time spent in helping the owner, and also the contractor, to a thorough understanding of his drawings, will enable him to carry out the work with greater satisfaction to himself and to all concerned. With a complete and accurate set of drawings and specifications, a fair and equitable contract, and a thorough understanding of these instruments on the part of all the parties interested, we are well equipped to begin operations at once.

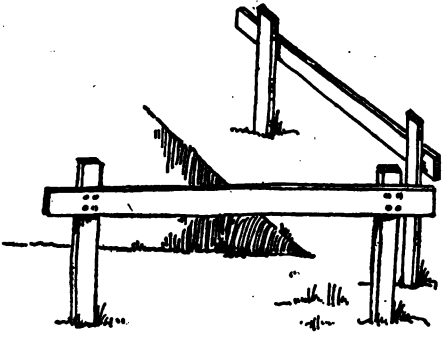


Fig. 6. Batter Boards

Staking Out. Upon the signing of the contract, arrangements are usually made for the architect and the contractor to meet upon the ground and lay out the building. The contractor for our house is required by the specifications to employ a civil engineer to lay out the work and set the batter boards. These consist of boards 6 or 8 feet long, as the case may require, securely nailed to joists which are firmly set in the ground at the corners of the cellar, Fig. 6.

Two boards are needed for each angle, and they are set 4 or 5 feet away from the line of the wall so as not to interfere with the excavation or with the laying of the cellar wall. Before proceeding to erect the batters, the position of the house will have been fixed by the engineer, by setting a stake at each corner, into the head of which is driven a nail marking the exact corner as indicated by the figured plans. This is often omitted but it is advisable as it gives a figure which corresponds to the dimensions printed on the plans, and any error can be more easily detected than when the lines for the walls are drawn. As soon as the corners of the house have been definitely located, the stakes for the batter boards are set and securely braced, and upon these stakes the batter boards are nailed with the top of the board at some given level, usually the top of the cellar wall. Between these boards, lines are stretched coinciding with the lines of the building as given by the small stakes; and when the lines are accurately drawn, notches are cut in the top of the board to hold and mark the place where the string belongs. If the stakes first put down were to represent the outside line of the sill, as is often the case, we must measure out and make a second set of notches for the underpinning, and back from this line measure the thickness of the wall, Fig. 7. It is often the custom to drive nails into the top of the batter boards, to which the lines are tied, but this is not a good practice, as the nails are likely to be pulled out of the board before the walls are finished, and are very likely to be driven in again in the wrong place. In addition to setting the batter boards at a given level, it is always well to establish in some permanent place, as upon the top of a neighboring ledge or on a stake firmly set and well out of the way of all building operations, a datum level or "bench mark", as it is commonly called, from which, at any time, the levels of the work may be given.

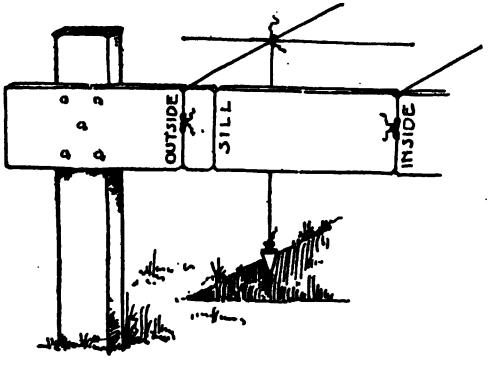


Fig. 7. Use of Batter Boards for Staking Out Building Foundation

Disposition of Materials. Before leaving the grounds it is well to instruct the builder where he can best deposit the material which will come from the excavations; and to place this to the best advantage, it is necessary to determine in a general way the position of the driveways or paths, and also to have a thought for future improvements and for the required drainage system. Unless this matter is taken up at this time it is very probable that the earth from the cellar will be left so near the excavation that it will have to be driven over or walked over during construction and then finally moved away to its destined use, as it should have been in the first place. The gravel will be needed for the driveways and paths, and space for this should be found not far away from the house; as the loam will be used where it is desired to have a good growth of grass and flower beds, this should be piled at the front of the lot, ample space being left for the convenient handling of timber and other materials. It will be necessary to consult the builder with regard to both this and the depositing of earth, that he may not later complain he has been hampered by lack of proper space.

CELLAR WORK AND FOUNDATIONS

DRAINS AND CESSPOOLS

Drains for Cellar Floor. The next visit finds the excavation of the cellar well under way. The earth has been removed, care being taken to make the outside walls conform to the dimensions of the foundation, and the cellar dug to the bottom for a great part of its extent. We proceed at once to examine the nature of the soil, and we find that while it is in the main a good coarse gravel, there is evidence toward the bottom of a clayey deposit which will hold water; and, indeed, in the trenches directly under the wall, which are to be 18 inches below the bottom of the cellar, water is standing in several places. Remembering that in the specifications it has been foreseen that the bottom of these trenches should slope to a corner of the cellar, we direct that the slope shall be made toward a hollow in the lot and that the trench shall be extended until it meets the surface of the ground in the hollow some 30 feet or more from the house. This trench, as well as the slope of the trench under the wall, we must make with a very slight pitch, lest the run of the water should wash away the soil under the wall and cause settle-

ment; and for greater security we must see that the lower foot of the wall which, according to the specifications, is "to be laid dry in the trenches", is *well laid* and not dumped or thrown in, Fig. 8. These stones should be neither large enough to choke up the trench and prevent the flow of water through it, nor so small as to be crowded into the ground by the weight of the walls over them. In any case, it is advisable to anticipate possible settlement by ramming the first layer of stones well into the bed of the trench. Where the soil seems to be somewhat soft or the weight of the building is greater than usual, it may be desirable to start the walls on broad footing stones carefully bedded upon the bottom. In this case it will be necessary to make the drain entirely outside of the wall, where it may be built of tile or stones. Indeed, but for the added expense of excavation and the increased cost of large footing stones, this method would be always preferable, Fig. 9.

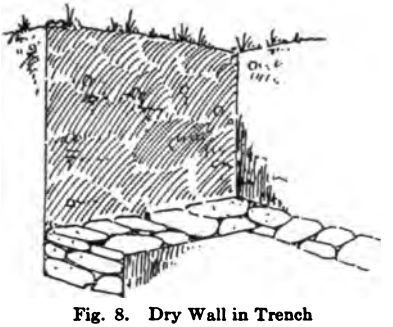


Fig. 8. Dry Wall in Trench

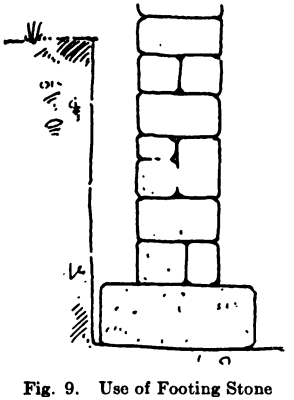


Fig. 9. Use of Footing Stone

If on the completion of the excavating there should be found any wet spots in the cellar bottom, these must be connected, by trenches filled with stone chips, with the main drain under or outside the wall, and in extreme cases the whole cellar bottom under the concrete should be filled with loose stones to a depth of about one foot.

Cesspools. In connection with the excavation of the cellar, we should take up the matter of a cesspool, provided there is no sewer connection available. In locating cesspools we must see that they are placed low enough to allow the drain from the house to have a good pitch. This drain will be of vitrified earthen pipe and should be laid at least 3 feet 6 inches below the surface, with an even pitch and with the bottom of the trench hollowed out where the hubs of the pipes will come, so that the pipes will lie flat in the trench.

Great care must be taken in jointing the pipes to make sure that the cement is scraped off the inside, since a projection would catch a portion of any solid matter which might pass through and the pipes soon become filled.

In building the cesspool we have a choice of methods—the leaching cesspool and the tight cesspool. In a great many cases where all danger of contamination of wells is obviated by a city or town water service, the cheaper method of a leaching cesspool may be adopted.

Leaching Cesspool. This consists of a circular excavation 8 or 10 feet in diameter and deep enough to reach to good leaching or absorbent earth. It is lined with a dry wall of stones laid with open

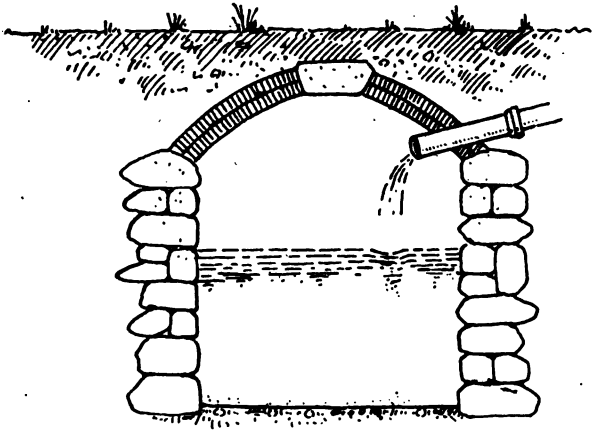


Fig. 10. Section of Leaching Cesspool

joints, and arched over on top with stone or brick forming a dome made water-tight, in the center of which should be set a stone or an iron manhole cover, Fig. 10. This may be finished at the level of the ground or kept low enough so that it can be sodded over. In good coarse sand or gravel a cesspool of this kind will dispose of the sewage of a house for a great many years, but eventually the pores of the earth will become filled with the deposits and leaching will no longer take place. An effective remedy in this case consists in making an outlet to which a series of pipes laid with open joints may be connected, to distribute the waste throughout a system of branches laid about 12 inches below the surface, where it will be absorbed and purified by the soil and growth.

Tight Cesspool. The other form of cesspool is what is known as a tight cesspool. It is constructed of hard brick and is usually made about 6 feet in diameter and 6 feet deep from inlet with walls and dome 8 inches thick and the bottom 4 inches thick, the whole cemented inside and outside and made perfectly tight, Fig. 11. This cesspool will retain the whole of the deposits and must be either frequently emptied, or an outlet made of open-jointed pipe as described in connection with the leaching cesspool. Such an outlet should be below the level of the inlet and should have a bend turned down below the surface so as to remain in the clear water which will be found under the scum of the surface. We find by the specifica-

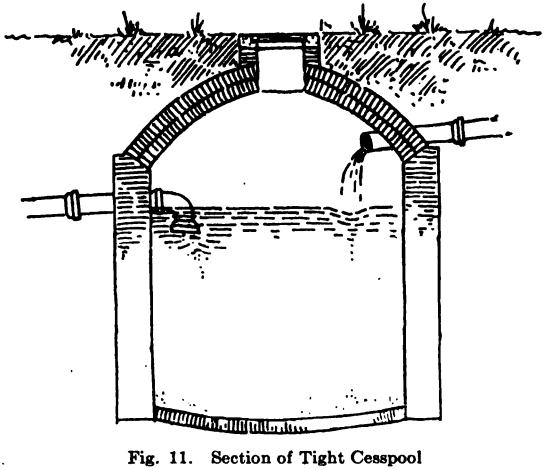


Fig. 11. Section of Tight Cesspool

tions that our architect has adopted a clever combination of these two methods by building two cesspools, one of which is a small, tight cesspool which will retain all the solid and putrefying matter and which is connected by an overflow pipe with a leaching cesspool built as described above. By this arrangement the tight cesspool will receive all of the solid matter which may be in the sewage and will hold it where it can be cleaned out at stated periods; the overflow, being of a wholly liquid nature, will pass into the leaching cesspool in a comparatively clear state and will be absorbed entirely by the surrounding earth with no perceptible contamination.

Dry Wells. As a part of the drainage system we must provide for the distribution of the rain water from the roofs. If our house

were connected with a sewer, we should simply connect the conductors properly with the main drainpipe in the cellar; but since we do not want this great amount of water to run into the cesspool, we will lead it away from the house by means of earthen pipes running from the bottom of the conductors to dry wells. These are excavations some 3 or 4 feet each way, filled with loose stones which are piled around the end of the drainpipes while the whole is covered with the grading, Fig. 12. The location of these wells will be determined by the position of the conductors, but they must be at least 8 or 10 feet from the cellar wall, and farther away if there is any danger of the water finding its way back to the cellar. The waste from the laundry trays, being of a comparatively clear nature, we will dispose of in the same manner.

Fig. 12. Section of Dry Well

CELLAR WALLS

While it is necessary to consider the matter of drainage at this time, the actual work of building the cesspools and laying the drain pipes is usually taken up at a later period, and the whole of our energy at this time should be directed toward the building of the cellar walls. Already the timbers for the frame are being delivered, and the contractor for the carpenter work is filled with forebodings lest he have no wall to put his sill on when the first floor is framed. We direct the mason to build the cellar walls with all the speed that he can, "consistent with good workmanship", and set ourselves the task of following him up sharply to see that this is done.

Quality of Stones. The greater part of the stone for the cellar walls has been carted to the lot and we shall do well to look it over with the mason, pointing out to him that many of the boulder stones are too round and should be split before being used, while some of the more slaty stones, which appear to have been recently blasted, may have cracks in them which will allow the water to soak in. This may be detected by striking the stones with a hammer to judge of their soundness by the clearness of their ringing. The stones, upon

the whole, are a good looking lot, and it remains only to see that the walls are properly constructed.

Method to Be Avoided. In the first place the walls must be built entirely free from the bank so that they are self-supporting, Fig. 13, and give besides an opportunity of cementing the wall on the outside, as called for. This is a thing generally neglected, and yet it is far more important than that the inside of the wall should be smooth and handsome. The ordinary careless way of building the cellar wall of a country house, is to lay the wall up to the top of the ground without mortar, stones of varying thickness being brought to a face on the cellar side, with the "tails" of the stones in

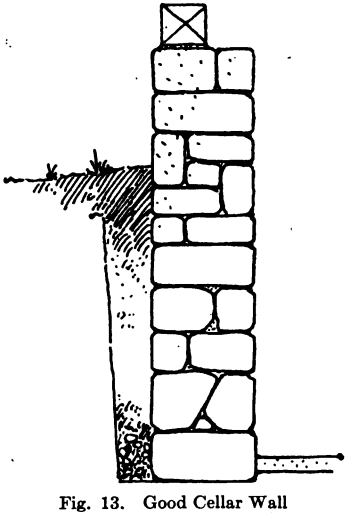


Fig. 13. Good Cellar Wall

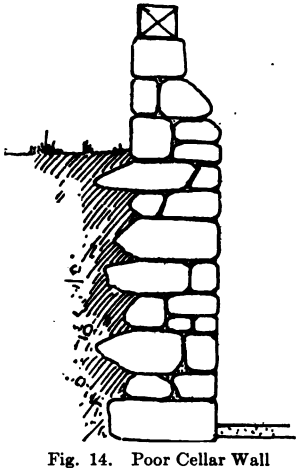


Fig. 14. Poor Cellar Wall

irregular projection on the outside, some partly resting against the bank and others barely filling out to the required thickness. The whole is finally smoothed over on the inside with a thin smearing of mortar, Fig. 14. This is a method which should be avoided for many reasons. In the first place, a wall of this kind is little or no protection against water, for the uneven projections on the external face serve to catch the water which runs down on the outside and to lead it into the inner face, where the thin pointing of mortar is very little protection. Then, too, any movement such as frost in the ground tends to overthrow the wall by reason of the long stones which tail into the ground, and often bear upon the soil in such a

way that any settlement or heaving of the soil will open cracks and cause the wall to bulge inward, as is often seen in country cellars. In reality it is more important to have the outside face of the wall smooth and impervious than the inside face. Satisfied that the stones which are being delivered are suitable for our wall, we shall need to give our attention mainly to the construction, to the mortar and bonding, to the solidity, and later to the pointing.

Mortar. The specifications require that all stonework below ground shall be laid in Portland cement mortar 1 to 3. This means 1 part of cement to 3 parts of sand, and makes a strong mortar. The portions which show above ground are to be laid in "half-cement" mortar, which we interpret to mean *equal parts* of cement and lime, and not *half* as much cement as lime, as some contractors will claim. This proportion of cement and lime with about 8 parts of sand will make a proper mixture; it should be thoroughly mixed as tested by the evenness of color and the smoothness.

For a wall particularly exposed to dampness, it would be well to use a stronger mortar than this, and to omit a large portion of the lime, only enough being retained to give a degree of smoothness to the mortar under the trowel. A proportion of 1 bag of Portland cement, 1 barrel of sand, ½ pail of well-slaked lime putty will make a strong mixture, and one that works easily. A workman's mixture which closely corresponds is measured by the shovelful: viz, 10 "shovels" of cement, 30 "shovels" of sand, and 1 "shovel" of lime.

Lime. In slaking the lime for mortar it is important that the water, in the proportion of 1½ barrels to 1 barrel of lime, should be added in as large quantities as is practicable, since putting the water in by bucketfuls and stopping to stir the mixture each time, tends to chill the lime which is already beginning to heat. After slaking, the lime must stand as long as possible before being mixed with sand, and the cement should not be added until the mortar is needed, since it will set in a few hours. To be of good quality, the lime should be free from cinders and clinkers; it should be in hard lumps and have little dust. It ought to slake actively and entirely, making a fine soft paste with no residue or "core". Lime should always be slaked in a pen built of boards, never on the ground or in a hollow in the sand. A pen about 4 feet by 7, and 10 inches deep, is large enough to mix a cask at a time.

Some kinds of lime when slaked leave a residue of stones and gravel, and when this is the case, instead of having the mortar made in the same box in which the lime was slaked, the mixture is thinned with water and is run through a fine sieve into another box. If Rockland lime is used, as is specified in our case, this operation will not be necessary.

Sand. The sand used should be sharp and free from dirt, loam, or other impurities. To obtain this, it is generally necessary to screen the sand. For our purpose a rather coarse sand will make the strongest mortar. It must be carefully inspected and in case of any doubt should be tested for purity. One test consists in putting a handful into a dish of water; any dirt or impurities will at once rise to the top as the sand sinks. Another test is to squeeze a handful of wet sand; if upon opening the hand, the sand retains its shape and soils the hand, it probably contains loam or clay and should be rejected; if it falls down loosely without staining, it is probably clean and good. The presence of fine loam in the sand will make the mortar work more easily and for that reason it is sometimes used by unscrupulous builders.

Cement. There are many brands of Portland cement, the kind called for by the specifications, and they are so well known that for ordinary purposes it is only necessary to see that the casks bear the name of the specified brand, and that the cement is fresh and has not become crusty from absorbing moisture. In case of doubt, simple tests of the setting quality and soundness may be made by the superintendent. For the initial set a small amount of clear cement may be mixed with water enough to make a stiff mortar, and the time noted which is required for it to set hard enough to support without indentation a wire $\frac{1}{12}$ inch in diameter under pressure of a $\frac{1}{4}$-pound weight. Good cement should not harden to this extent in less than 30 minutes.

To test for soundness, mix some cement with a little water in several pats about $\frac{1}{2}$ inch thick and 3 inches in diameter, running to a thin edge. After these pats have been kept under a damp cloth for about 24 hours, place some under water and leave some exposed to the air for a few days. If the cement dries in the air with a light color and free from cracks, and sets under water with a darker color and free from cracks, it may be considered of good quality; but

if any one of the cakes cracks or becomes twisted and bubbly, it shows a quality of cement which is inferior and should be rejected. Cement must be kept in a dry place, for a little moisture will cause it to set and it will soon become worthless.

Construction of Wall. Upon our next visit, we find that the trenches all around the cellar have been filled and a portion of the wall laid, starting from the corner and running some ten feet in both directions. Our first care is to examine the lines by which the work is being laid up. We note that each line is tied to its proper notch on the batter boards and that the men are working to plumb lines hanging at intervals from the long lines, Fig. 7, using the stones about as they come to hand, the only preparation being to square the too irregular ones, to make a face on them by the use of the stone hammer. We caution the mason to level off the wall about every two feet, Fig. 15, and to keep the horizontal joints as near to a level as possible. We also call his attention to the clause in the specifications which stipulates a bond stone in every 10 square feet of wall, and we carefully examine the wall already built to see if this has been done. In a wall such as we require, that is, one with practically two faces, there is often a tendency to build the two faces with long narrow stones and to fill in between with small stones which are put in nearly dry with a little mortar on top to show well. Such a wall has an appearance of strength on the faces, but under a heavy load may fail from lack of bonding. To detect this defect in a wall already built, but before the mortar has set, a very useful instrument is a steel rod about $\frac{3}{16}$ inch in diameter and 4 feet long. Thrust down into the center of the wall, this will show at once whether the stones are laid to overlap each other or not, and also whether the stones in the center are well bedded or not, as they will rock and jar when struck with the rod if not thoroughly bedded. No stone should be set with a depth from the face of less than 6

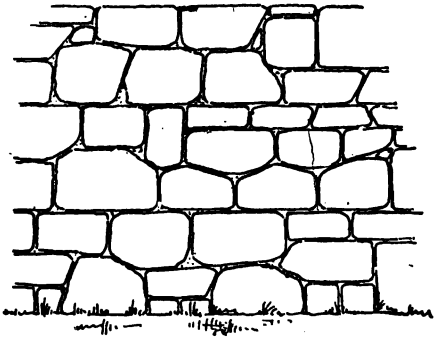


Fig. 15. Rubble Wall Leveled Off

inches, and all stones should be laid so that their split surface is horizontal, breaking joints in the length of the wall, as well as through and through, and all angles should be bonded alternately, the largest stones being used for the corners, Fig. 16.

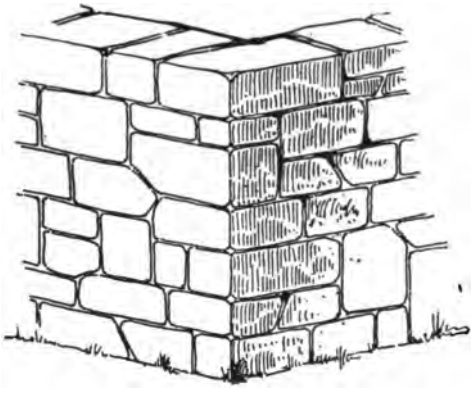


Fig. 16. Rubble Wall Showing Corner Construction

The corner which has been built we find to be well bonded, as the first corner of any wall is likely to be when stones are plenty and near at hand—it is the last corner of a cellar wall which will need the sharpest watching—but about six feet from the corner we discover a line of vertical joints which runs irregularly but continuously through four or five courses, *A*, Fig. 17. We call the man who is working upon this part of the wall, and point out the defect to him with instructions to take down the wall until he can bond over the second course, and we caution the foreman to watch sharply against this sort of construction. Another bad practice which some masons encourage is that of filling the spaces between the larger stones with chips or pebbles, put in dry and then smeared over with mortar more or less carefully worked into the seams. This kind of work is easily detected by use of the steel rod, which we can feel moving the stones if they are poorly bedded. The right way is to settle each stone, no matter how small, into a bed of mortar, either by rubbing with the fingers or by tapping with the trowel or hammer. In heavy work all large stones should be set with a derrick, for in rolling the stones up to their places on

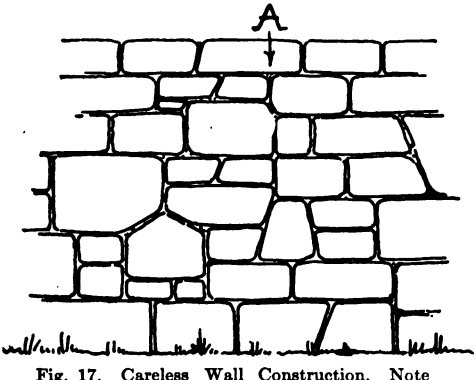


Fig. 17. Careless Wall Construction. Note Straight Joint *A*

planks set up against the freshly laid wall, there is not only danger of shoving the wall out of plumb, but the bed of chips and mortar which has been prepared is sure to be torn up, and there is no certainty that the stones are properly bedded. Satisfied with the work which has been done so far, we give orders that the filling in against the walls be done with coarse gravel or broken stone, well puddled with water or settled by ramming.

Concrete Walls. The custom of using concrete for cellar walls in place of stone is constantly growing. This is a good practice when the concrete is properly made, and it is often, also, a saving of expense over a stone wall. In any case, concrete is the best material for the footing course which bears directly on the ground, as it naturally fills all inequalities in the bottom of the excavation, besides distributing the load better than a footing of separate stones or other materials.

Underpinning. The next visit finds the cellar wall complete up to grade and the excavation filled in to the natural level of the ground. While we have no reason to suspect that our instructions have not been followed with regard to facing the wall on both sides, we nevertheless have recourse to the steel rod. Thrusting it down alongside the wall at intervals, we do not find any projecting stones, and as the digging away of the filling in several places shows that the wall is properly cemented on the outside, we feel reasonably sure that the wall is built according to contract. We next take up the question of the underpinning, the portion of the cellar wall above ground which, being visible, must be considered from the point of appearance as well as of strength. A variety of materials may be used for the underpinning. Long pieces of granite or freestone in one or more courses are often used; sometimes an 8-inch brick wall is built upon the stone of the cellar; often the wall already built below ground is continued up to the sill, except that above ground, the face joints, instead of being carefully filled are left without mortar for about $\frac{3}{4}$ inch from the surface, to be filled later with Portland cement mortar, colored as preferred and rubbed with a tool made for the purpose to give either a concave, V-shaped, or raised joint.

It is important to see that the underpinning is carried up to the sill the full thickness of the wall, spaces being left for girders, and the top carefully leveled off at the bottom of the sill.

FRAMING

Sills. While the walls were being built, the carpenters have been at work framing the house and they are now ready to lay the sills and put on the first floor beams. The preparation of the sill consists in halving and pinning together at the corners, Fig. 18, mortising for the door and window studs, and notching out for each floor joist about two inches down into the top of the sill. The sill should be well painted on the underside as a protection against moisture from the wall, but unpainted elsewhere to allow drying out, and it should be set in a thick bed of mortar. As our sill is to set back two inches from the face of the wall, we shall have a chance to point up with mortar along the outside edge to be sure that there is no chance for cold air to get into the floors at this point.

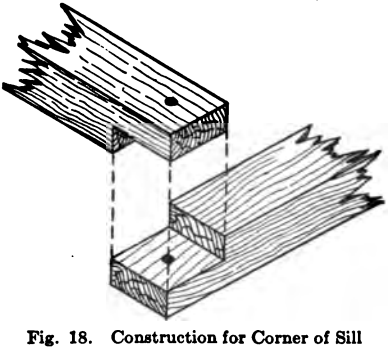


Fig. 18. Construction for Corner of Sill

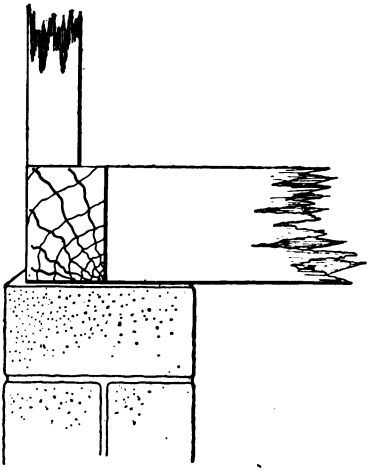


Fig. 19. Proper Construction for Sill on Wall

Custom allows much variation in the size of the sill, 6×6 inches being the most common size; 6×8 inches is called for in our case, and sometimes the sill is made 6 inches by the depth of the joist. Where large sizes of timber are easily obtainable, this last method is to be recommended. In the first place, the greater depth of timber will span all openings that are likely to occur in the cellar wall, and, besides, the equal depth of the sill and joists leaves no space between the cellar and the vertical wooden wall and prevents, without recourse to brick filling, Fig. 19, the circulation of fire or vermin. The sill may be bolted to the wall, but this is not usual except for light framing in exposed situations.

Girder Supports. After the sills are set, the next timbers to be put on are the girders which carry the inner ends of the floor beams. They are generally set under the bearing partitions of the house and supported by brick piers or iron columns in the cellar.

Brick Piers. Since the piers or columns are not usually set until after the heavy floor beams have been put on, as they would be in danger of being knocked over in the handling of the heavy timbers, the timbers are in most cases supported by shores until the piers are built. Piers of the height of an ordinary house cellar should be 12×12 inches, spaced, according to the size of the girders, from 7 to 9 feet apart.

Iron Columns. Where available, iron columns may be used as a good substitute for brick piers. They take up less room and are more easily and quickly placed. For ordinary cellar work, there are in the market columns made of wrought-iron pipes, filled with a carefully prepared cement concrete, which cost less than brick piers. These columns come in convenient lengths, fitted with a cap and base, ready to set and secure to the timber. From 3½-inch to 5-inch sizes are large enough for house work.

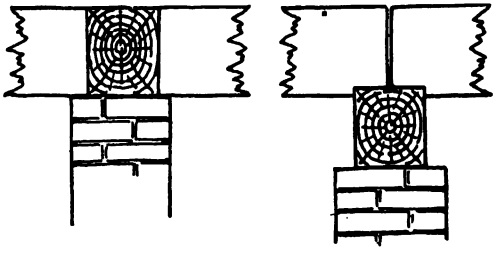


Fig. 20. Diagrams Showing Typical Flush and Drop Girders

Girders. The girders are usually 6×10 inches or 8×10 inches for the floors of a wooden house—in our house 8×10 inches. In their vertical position, the girders may be set flush with the floor timbers, in which case each joist is framed into the girder, or they may be dropped to allow the joists to rest on top, usually notched an inch into the girder, Fig. 20. The advantages of the flush framing are that the shrinkage of wood at each end of the joists is equalized, that the circulation of fire by means of the interior partitions is prevented, and that the girder does not take headroom out of the cellar. The advantages of the dropped girder are that the full strength of the girder is available, and that it is possible to run hot-air and other pipes up in the partitions without cutting the girder.

If flush girders are used, the position of mortises, as well as the position of the mortises in the sill, should be examined by the superintendent to see that the openings framed for chimneys, stairways, etc., are correctly laid out according to the framing plans. Obvious errors will, of course, be easily detected, but it will save much annoyance later if every mortise is verified before the floor is put on.

First or Rough Flooring. After the girders are placed the floor timbers may be set. These are usually 2 inches in breadth and for our house are 10 inches deep. Upon these joists is invariably laid, in the East, a rough floor of $\frac{7}{8}$-inch boards either of spruce or hemlock, upon which the workmen can move to carry out all subsequent operations. It has been the custom in the West to omit this under floor, but the saving in expense is very slight and the benefits of the double floor are many. In the first place the under floor stiffens the building perceptibly; then it is of great convenience to the workmen, and allows the laying of the upper floor to be put off until the very last thing. This is an important consideration in these days of bare floors and has led to the adoption of the rough under floor generally. It is a good plan to lay this floor diagonally with the joists, as this greatly stiffens the building and gives a more even surface upon which to lay the upper floor.

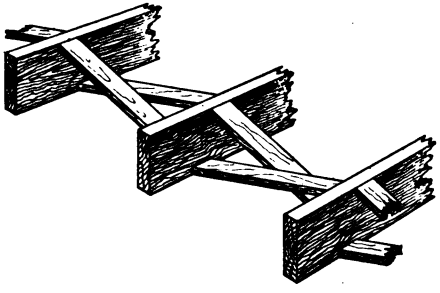


Fig. 21. Proper Method of Bridging Joists

Bridging. As soon as the rough floor is laid, and before this if the boards are to be laid diagonally, the floor beams must be bridged, or trussed as it is sometimes called. This consists in cutting in diagonally between the joists, strips of wood which are nailed securely top and bottom and cross each other between each two timbers, Fig. 21. Some carpenters reason that a piece of plank cut in vertically between the joists will serve the same purpose, but this is not so. If the floor is laid square across the joists, the usual way is to take up a board along where the bridging will come. The superintendent should make sure that the bridging is well fitted, thoroughly nailed, and continuous from side to side.

Exterior Framing. Next in order comes the raising of the exterior vertical frame, and in this operation we have a choice between two principles. The first and more common method is called the "full frame" or "braced frame" and consists, first, in erecting at the angles of the building, posts 4×6 or 4×8. Between these uprights, at the level of the floors, are then run horizontal girts which receive the joists of the second floor and into which are framed the door and window studs. At the top of the wall a plate is set in a similar fashion. The angles made by these timbers with the posts, are each braced by diagonal pieces framed or spiked to the horizontal timber and to the post, Fig. 22.

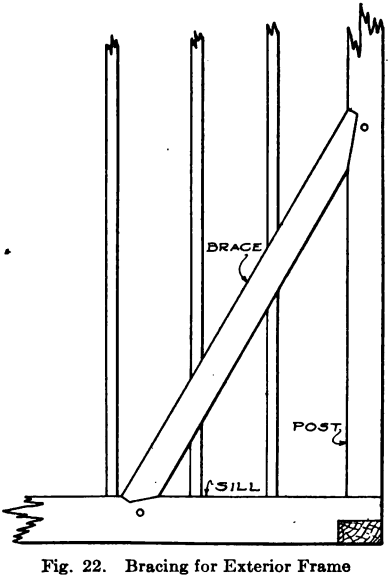


Fig. 22. Bracing for Exterior Frame

In the other method of exterior framing, called "balloon framing", the girts are omitted and the studs run from sill to plate. The usual way of forming the plate in this construction is to spike on the top of the studs a 2-×4-inch piece, and on top of this another 2-×4-inch piece, breaking joints and overlapping at the angles. Provision for supporting the intermediate floors is made by spiking a board 1×6 inches into notches cut in the inside of the studs so that the top of the board will be an inch above the bottom of the floor joists, Fig. 23. This board is called a ledger board. It is one of the weak points of balloon framing, not in the weight-carrying sense, but because of danger in case of fire, since, being more easily consumed, it does not prevent the spread of the fire as would a solid girt, and would, doubtless, let the floor fall. The floor joists should be notched over this ledger board, which should be kept back a little from the inside face of the studs to allow space for the mortar to clinch. Another weak point in balloon framing is the matter of braces. If used, the braces can be only short ones at the top and bottom, but they are usually omitted. A substitute sometimes

used, is a stout strip, usually 1 inch by 3 inches, cut diagonally into the outside of the studs and spiked to each. This makes a very strong brace but weakens the studding. The fact that the studs of a balloon frame run from top to bottom requires that the windows should be as nearly as possible over each other, so that one set of window studs will serve for both upper and lower windows.

Erection. The erection of the outside frame should be carefully watched to see that the door and window studs at least are tenoned head and foot, that all the braces are put in and properly framed, and that all the joints are snug and well pinned, the openings in the proper places, and the framing plumb and rigid. Nothing is more annoying than to find, after the outside frame is all up, that a window or door has been framed out of place, and although the builder may be obliged to rectify the mistake at his own expense, it can be done only by patching somewhere and the owner is very likely to feel that the error might have been prevented by the architect's more careful supervision.

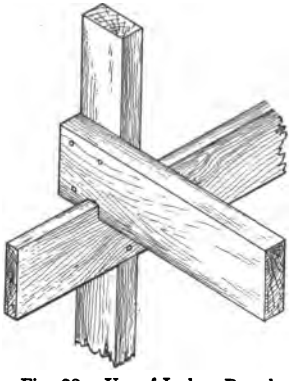


Fig. 23. Use of Ledger Board

Outside Boarding. As soon as the frame is set up, for our house a full frame which can be set up a story at a time (the attic joists only being carried on a ledger), the outside boarding is put on. Spruce or hemlock is used for this mainly, but it must be mill-planed to an even thickness so as to give a true surface for the outside covering of clapboards or shingles. We find that it is specified that the boarding shall be matched and laid diagonally upon the walls, and square-edged for the roof. The reason for not matching the roof is that the cracks in the square-edged boarding allow circulation of air under the roof shingles and preserve them much longer than if matched boarding were used.

Inside Bearing Partitions. When the first-story studding is up and the girts are on, the inside bearing partitions must be erected to give a support for the inner ends of the second-floor joists. It will not be necessary to set up all the studs of these partitions at first, but the partition caps should be run and studs put up at three-

or four-foot intervals, and as nearly as possible in their proper places, to avoid doing the work over again. As soon as this is done, the second-floor joists can be set and bridged and, with the outer walls carried up to the plate and another partition in the second story set, the attic joists may be put on and the building made ready for the roof.

At this juncture we are approached by the foreman who holds in his hand a smooth board upon which he has drawn a sketch of the attic joists and ledger board which he submits for our opinion. We examine his drawings and find that he has represented a ledger board 2×3 inches, notched into the studs one inch and up into the joists two inches, making the bottom of the ledger flush with the bottom of the ceiling furring, Fig. 24. This method he puts forth as having strength nearly equal to the 1-×6-inch board which is generally used, and the merit of not presenting so broad a surface behind the lathing at the top of the second story, which destroys in a measure the key of the plaster. We consider carefully this method in all its aspects and, admitting that it has these features to recommend it, we can praise the ingenuity of the device. If we were to run heavy cornices at the top of our second story we should be inclined to adopt the sketch, but as we shall run only a picture molding in the angle which would be helped rather than hurt by the presence of the wood behind the lathing at that point, we decide in favor of the usual way of putting in the 1-×6-inch ledger, but tell the foreman to notch the studs $1\frac{1}{8}$ inches deep so that there will be a space between the laths and the ledger for a key to the plaster, Fig. 23.

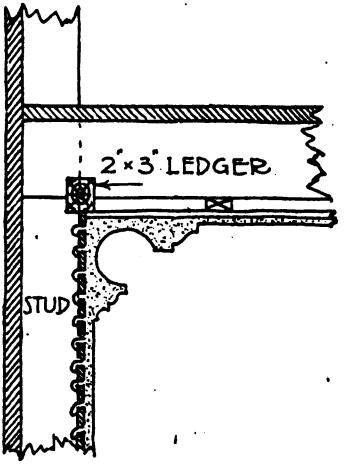


Fig. 24. Section Showing 2- 3-Inch Ledger Board Sometimes Used

Avoiding Unequal Shrinkage of Timber. An important matter in carrying the outside and inside supports from bottom to top is to see that the amount of shrinkable timber is, as nearly as possible, the same in both outside and inside walls. For this reason the com-

mon practice of setting the partition studs upon a horizontal piece laid on the under floor should be avoided, Fig. 25. For instance, in our case the amount of horizontal wood in the outer wall from the rigid underpinning to the attic joists will be as follows: the sill, 6 inches; the girt, 6 inches; and the upper part of the ledger board above its nailings, 2 inches—in all, 14 inches of shrinkable wood. If the inside partitions were set on a 2-inch sole resting on the under floor in each story, there would be in the inside wall, from the rigid piers in the cellar to the under side of the attic joists, the following amount: the girder, 10 inches; the two tiers of floor beams with under floors, 11 inches each; and two soles and two caps, 2 inches each—making, in all, 40 inches of wood, the shrinkage of which would amount to an inch and a half or more as against a probable half-inch on the outside walls. The result, when the house has become completely dry, would be that the inner end of the floor beams would be an inch or more lower than the outer end, enough to crack the plastering, and make doors bind in the cross-walls of the second and third stories. The remedy for this is to let the studs of the first story stand on the girders, and the studs of the second story stand on the cap of the first-story partition, and so on, so that the floor timbers do not form a part of the vertical frame, Fig. 26. This will give, in the case of our house, an amount of horizontal wood equal to the girders, at 10 inches, and the two caps at 2 inches each, making 14 inches in all, about equal to the horizontal timber in the outside frame.

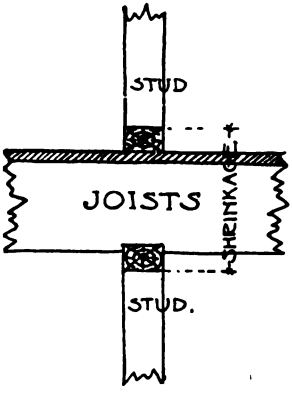


Fig. 25. Wrong Way of Setting Partition

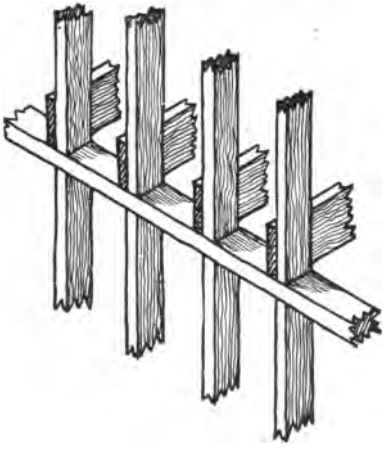


Fig. 26. Right Way of Setting Partition

Partitions running through two or more stories which do not carry floor beams should be built in the same way. Partitions which have no corresponding partitions under them will often occur and will be found in two conditions—those running parallel with the floor beams, and those running across the floor beams. In the former case it will be necessary to set two floor beams under the partition, spaced far enough apart to give a good nailing for the ends of the upper floor boards. In the latter case it will be necessary only to lay down upon the under floor a sole 2 inches thick by the width of the studs.

An important matter in relation to the leveling of the floors is to see that all measurements for sizing-down of the timbers are made from the top of the timber, so that the floor will be level on the top and any inequalities in the depth of the joists can be taken up in the furring. A half-inch will usually be enough to overcome the differences in the depth of the joists so that a series of 10-inch joists should be set with their tops 9½ inches above the girder or partition cap upon which they rest.

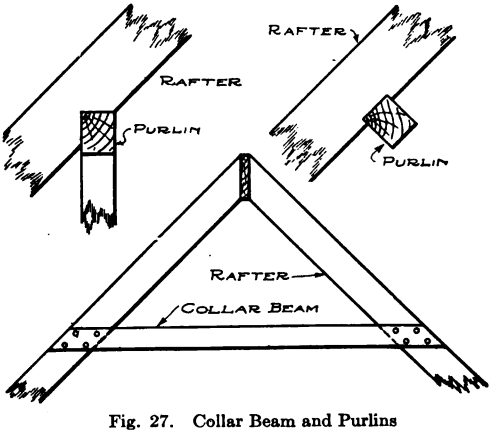


Fig. 27. Collar Beam and Purlins

Roofs. As soon as the attic floor is on, the roofs will be raised. In ordinary country houses the roof should be supported where possible by the interior partitions where these extend down to first-floor girders over basement piers, for in this case no complicated framing or truss work will be required. The usual form of roof consists of a series of rafters supported at the bottom by the plate of the house and at the top by the ridgepole. Intersecting roofs are supported by large timbers called valley rafters and these should always continue up to the ridge. If the rafters are over 18 feet long it will be necessary to support them near their center; this is done by partitions or by collar beams spiked across

from rafter to rafter, Fig. 27. In large buildings they are supported by purlins resting on trusses or on posts. The spacing of the rafters varies from 16 inches to 2 or 3 feet, 20 inches being the most usual distance.

For any roof of less than a 30-foot span with the plate securely tied, no interior supports will be needed; for roofs of greater span, purlins should be used. The size of rafters not over 12 feet long should be 2×6 inches; from 12 to 18 feet, 2×7 inches and 2×8 inches; and over that length, 2×10 inches. On the whole it will be cheaper to reduce the length to 10 or 12 feet by means of purlins. An examination of the framing plans shows that our rafters are about 15 feet long and 2×7 inches in size, set about 20 inches on centers. The roof is a hip roof, that is, a roof which draws in from all sides; this is the strongest kind of roof, and we shall not, therefore, have to provide any special supports, and shall only have to

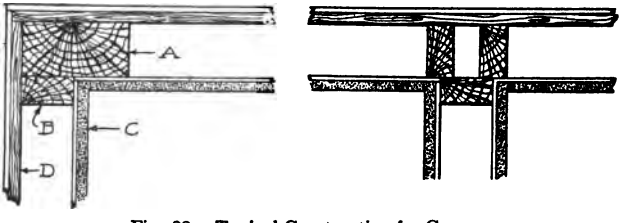


Fig. 28. Typical Construction for Corners

see that the correct pitch is given according to plans, that the valleys are properly put in and are extended to the ridge or to the hips, and that the openings are of the right size and in the right positions. All portions of the roof must be well spiked together, the ridges perfectly straight and level and in the center, and the rafters all set exactly to a line.

Partitions. With the covering-in of the building finished we may turn to the completion of the inside partitions, and these must be carefully followed to see that the studs are straight and plumb. Crooked studding may be straightened by cutting with a saw on the concave side and then wedging the cut apart. All studs which bear an extra weight, as those at the sides of large openings, should be examined to see that they have a sufficient support on the partition underneath, and do not come between the studs; in case they do, a block should be cut in under the par-

tition cap, which should also be done where heavy timbers bear between studs. The corners must be examined to see that they are made solid for lathing, Fig. 28, and that provision is made for running pipes, etc. If any of the unsupported partitions running parallel with the joists are found to have a considerable span so that there is danger of too much sagging, the difficulty may be overcome, at a small cost, by trussing the partition, and if such a partition is used in any way to support floors or other partitions overhead, this should always be done. The studs at the sides of all openings are to be doubled, and all openings of more than 3 feet are to be trussed. The head of every opening should be doubled, with the lower piece 1 inch from the upper, so that if there is any sagging of the upper or weight-bearing piece, that will not affect

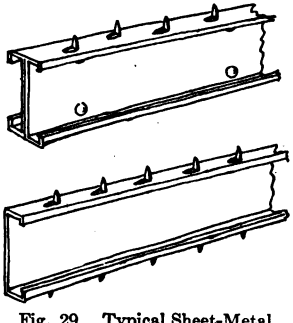


Fig. 29. Typical Sheet-Metal Joists and Beams

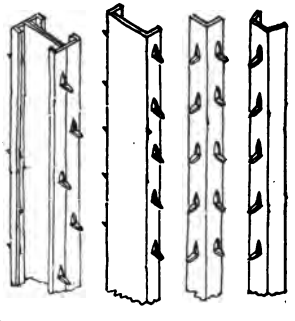


Fig. 30. Structural Steel Shapes with Prongs to Hold Metal Lath

the lower one to which the finish is nailed. All the partitions should be bridged, and all sliding-door pockets sheathed with end joints secured, to avoid every possibility of a board starting off. The lining of sliding-door pockets should be set upon heavy sheathing paper in such a way as to prevent the very annoying air drafts from the cellar.

Sheet-Metal Joists and Beams. Of a later development are the various patterns of framing-members constructed of sheet metal in shapes to perform the offices of girders, joists, studding, rafters, and other parts of the skeleton of a house. The beams of different makes consist in the main of a web member and flanges, either formed of a single sheet or riveted together in the form of I-beams, T-bars, and other shapes common to rolled steel, Fig. 29. These,

being made of sheet steel, are somewhat limited as to strength compared with rolled-steel shapes, but they are well adapted to houses, ordinary public buildings, and mercantile buildings where moderate loads are to be carried. In many of their shapes the sheet steel of the flange or web is pierced and forced out in the form of prongs, Fig. 30, to which metal lathing may be secured by bending down the prongs, thus making a metal structure which is light and can be quickly erected up to the point of plastering.

MASON WORK

Chimneys. While these matters are being followed out by the carpenter, the mason must have started the chimneys, since the roof cannot be finished until the chimneys are topped out. The bricks which are furnished should be carefully inspected, and any that are soft, or easily broken by striking together, should be ordered off the grounds at once. The specifications call for good hard bricks. If the contractor is honest he will have ordered suitable bricks, and if they are rejected the loss will be the dealer's and not his.

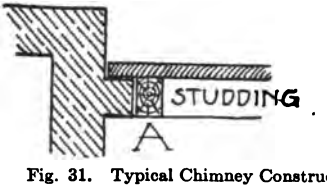


Fig. 31. Typical Chimney Construction

Inside of Chimney. Next in importance to the quality of the brick is the smoothness of the inside of the flues; this is best secured in unlined flues by cleaning off with the trowel the mortar which squeezes out of each joint as the bricks are laid. In some localities it is customary to plaster the inside of the flues with mortar, but there is always danger that after a while this plastering may become loose and block the flues. Chimney bricks should be laid solid in mortar, so that no cracks are left for the passage of sparks. The best plan, and what is specified in this case, is to use linings of vitrified clay. These not only give a smooth flue, but add strength to the chimney and permit the use of 4-inch walls everywhere. All ash doors, clean-outs, and thimbles should be of ample size, and set as the work goes up, and the withes bonded

into the outer walls every 6 or 8 courses, Fig. 31. This will not be done unless close watch is kept by the superintendent.

Outside of Chimney. The rough fireplaces must be formed, with wrought-iron bars over each opening, and the outside of the chimney must be thoroughly plastered from cellar to roof. The topping out of the chimney is to be done with the hardest of the bricks laid in Portland cement mortar. If there is planned an enlargement of the chimney where it shows above the roof, this must be done below the roof boards so that there may not be the overhanging projection of the bricks just above the roof often found in old chimneys, for the settlement of the chimney, which is likely to occur, will leave the top supported by the overhang upon the roof and open a dangerous seam at this point. The settlement of chimneys is a matter which it is necessary to consider at all times as it is almost certain that there will be an unequal movement between the chimney and the house. If the chimney stands upon a ledge or other immovable foundation, the roof will invariably settle a little because of the natural shrinkage of the wood construction; but more often the chimney, by reason of its isolated foundation and the general shrinkage of the mortar joints, will settle more than the roof.

Method of Attachment to Roof. This danger of settlement, as well as the danger from fire, precludes direct attachment to any portion of the wooden construction. The chimneys are generally built, therefore, entirely free and are secured to the frame by strap-iron ties, which bend enough to adjust themselves to any settlement, either of the chimney or of the frame. In the case of outside chimneys, where protection from the weather becomes necessary, this natural movement between the chimney and the house must be recognized, and the chimney should be constructed with a projection of brick in line with the frame so that the boarding may run over and break the joint, *A*, Fig. 31. Where the top of a small chimney stands clear above the house for more than 10 or 12 feet, it should be stayed to the roof with iron rods. Two rods should be used, spread as far apart as possible at the point of junction with the roof, to give a measure of lateral support to the chimney. Lead for counter-flashing is to be furnished by the carpenter, for the mason to build into the joints of the chimney above the roof boarding, and

care must be taken to see that the pieces are of good size and are carefully cemented into the brickwork at least 6 inches above the roof, and that they are ready to be turned down over the flashings which the carpenter will build in with the shingles. Behind the chimney, the flashings must be built in to a height that will allow proper room for building a saddle, to turn the water to either side.

Caps. When the stone caps for the tops of the chimneys arrive, they should be carefully measured on the ground, to be sure that they are of the correct size and that the holes for the flues are large enough, of the right shape, and in the proper position. For a large chimney with thick walls, it may be necessary to make the stone cap in pieces, and when this is done, the stones must be carefully tied together with galvanized iron or composition clamps. The excessive projection of bricks to form the chimney top is a thing to be avoided, $\frac{1}{2}$ to $\frac{3}{4}$ inch to each course being all that should ever be allowed. In determining the projection of the top, it must always be remembered that the projection at the corners will appear greater than the natural projection of the courses, and there will be more danger of finding the completed top too large than too small. Projections from the shaft of the chimney must be protected on top by a weathering of Portland cement, and where an outside chimney is reduced in size the weatherings should be of stone.

Back Plaster. With the topping out of the chimneys, the mason, who in suburban work is very likely to be the plasterer as well, should turn his attention to the back plastering, if there is to be any. The back plastering is done in several ways, a common method being to nail strips to the sides of the studs and to lath upon these, the whole surface between the studs being covered with a rough coat of plaster, Fig. 32. Care must be taken to bring the mortar well out on the studs, and even then when the studs shrink there may be a continuous crack along the side of the stud from top to bottom. This, if it happens, will defeat the whole purpose of the back plastering and it is so likely to occur that other means than those just described are often taken to obtain a better result. One of the best methods is to lath the house on the studding and to put on a rough coat of plaster, then to fur off with $\frac{7}{8}$-inch strips and lath and plaster again for the finished work, Fig. 32.

Fire Stops. In connection with the back plastering, may be done the fire-stopping of plaster or bricks. The principal point is to build with brick on the underpinning behind the sill up to the underside of floor, not only to prevent the spread of fire, but also

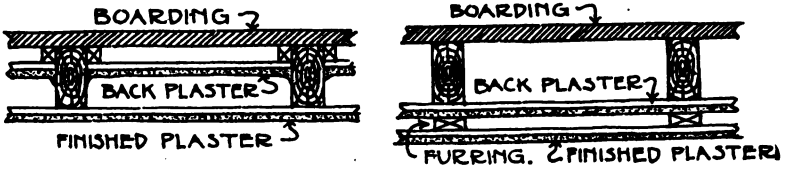


Fig. 32. Two Methods of Finishing Off Back Plastering

to prevent rats from going from the cellar up into the walls and so all over the house. On the top of girders the same thing should be done, and if the girders support partitions, the brick work should be carried up between the studs for a distance of 3 courses or more above the floor, Fig. 33. By repeating this operation upon each partition cap and upon the girts of the outside frame, the whole house will be cut up into compartments and the circulation of fire and

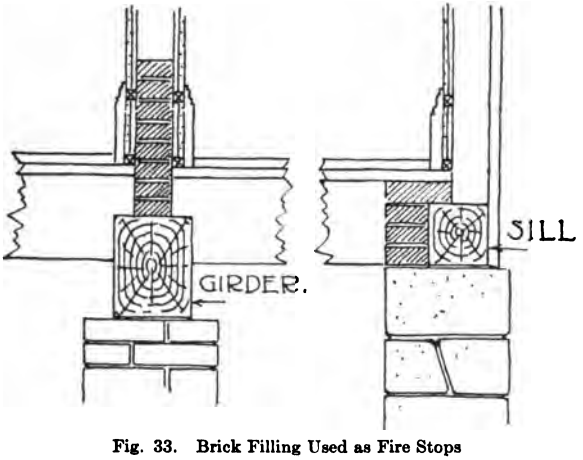


Fig. 33. Brick Filling Used as Fire Stops

vermin materially checked. In the case of a balloon frame where there are no girts, it is customary to run the floor boards out between the studs and to build up on these with the bricks. A further precaution, and a valuable one, is to lay a few courses of bricks upon

the bridging of partitions; this will cause any fire which may have started below to break out in the lower room, where it will be discovered before it is likely to reach the story above. The spaces between stair stringers and around chimneys should also be protected by fire stops of brick or plaster.

OTHER OPERATIONS CARRIED ON WITH FRAMING

Framing Details. As soon as the roof is on and boarded, the gutters will be put up and the roof shingling begun. The position of the gutters must be carefully noted to be sure that the edge is on a line with the roof boarding, for otherwise the gable finish will not work out correctly. The position of the conductors should be determined, and the gutters set with a slight fall toward them, and holes for the lead goosenecks should be bored, in order that no water shall stand in the gutters. With the completion of the gutters the shingling or slating of the roof can be commenced, and before the roof is completed the furring of the inside will be discussed.

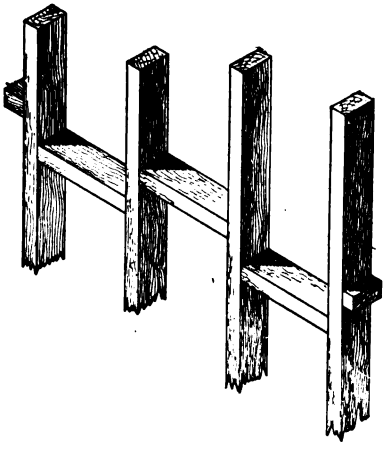


Fig. 34. Horizontal Bridging of Partitions

Beyond the setting of minor partitions which were not needed for the support of floor beams, the principal work of interior framing will be the furring of chimney breasts, and the forming of beams and arches. The position and size of every door must be carefully verified, especial care being taken to allow the proper width for door casings where doors come close to the corner of any room. When the studs of all interior partitions are set up they must be bridged. This is often done by cutting in horizontal pieces between the studs, Fig. 34; but a better way is to cut in the pieces diagonally, Fig. 35. The chimneys must be enclosed by vertical studs, usually 2-×3-inch or 2-×4-inch, set flatways and at least an inch away from the brick, Fig. 36, with an ample, well trussed opening left for fireplaces. All door openings must also have a truss over them, and

any partitions which have no adequate support beneath should be trussed, if the arrangement of doors will by any means allow it.

The ceilings will be cross-furred with $\frac{7}{8}$-×3-inch strips, commonly called "strapping". These strips should be carefully leveled

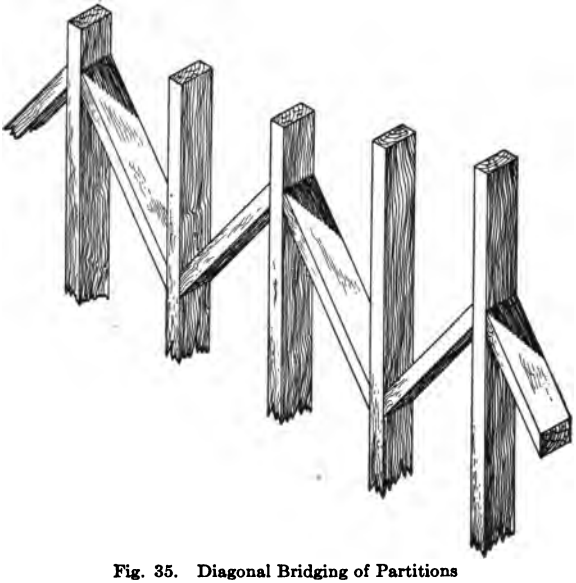


Fig. 35. Diagonal Bridging of Partitions

and straightened, since upon their evenness depends the smoothness of the ceiling; above all it is necessary that the strips be well nailed to every joist. Grounds are next set and angle beads for lathing,

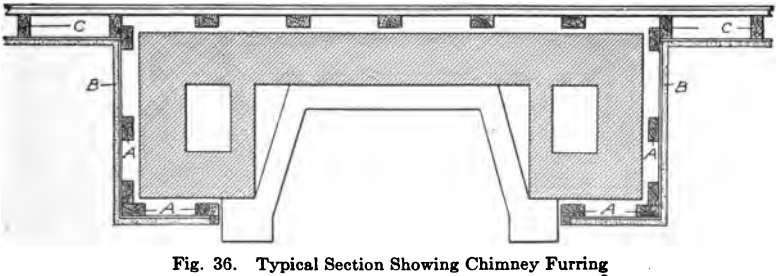


Fig. 36. Typical Section Showing Chimney Furring

but before any laths can be laid there are a number of things to be considered.

Furnace Pipes. In the first place, all hot-air pipes which are not to be exposed must be put in position. If a hot-air system has

been selected, the position of the pipes and registers will have been marked on the plans, but frequently in the execution changes suggest themselves or are required by unforeseen circumstances, so that the superintendent should make a personal study of the piping at the building. Where it is possible to arrange it, the pipes should be run through closets, exposed to view; but this cannot always be done, and it often happens that the chimney breasts and sometimes the partitions must contain hot-air pipes. The best and safest way to do in that case is to make the pipes double with at least a half-inch air space between the outer and inner pipes. This is expensive and is not generally done; instead, the woodwork which comes close to the pipe is lined with bright tin, and heavy wire lathing rather than wood laths is used in front of the pipes. Where the pipes are carried through the partition or woodwork, a sleeve of bright tin a half-inch larger than the pipes should be provided as a safeguard against the overheating of the pipes.

Ventilation and Gas Pipes. Although it is customary nowadays to run the plumbing pipes outside of the plaster, there are some ventilation pipes that need to be provided for at this time. All of the enclosed gas-piping must be done before lathing. From the fact that the gas-piping must be carried in almost every case to the center of the ceilings, there is need of careful watching lest the cutting by careless workmen weakens the joists. The specifications distinctly state that no floor beams shall be cut into, more than 2 feet away from their bearing, but as this means that all outlets in the centers of ceilings must be reached by branch pipes between the joists, and as this entails more piping and labor for the gas-fitter, there is a great temptation to disregard instructions and to cut the joists for a straight run from center to center of rooms. Only constant watching will prevent this being done. Care must be taken that the pipes are run with a continuous drop toward the meter, to allow the liquid, which is always condensed from the gas, to run off; and, for the same reason, wall outlets must be piped up from below, and ceiling drops should be taken out of the *side* or *top* of the pipes. The position of all outlets must be verified, especially those which are centered in the rooms, and they must be set at right angles to walls and ceilings. This can be proved by screwing on each outlet, as soon as set, a piece of pipe a foot or more in length and testing with

a stee square. No "gas-fitters' " or other cement should be allowed, but all pipes should be put together with red lead. The outlets to receive fixtures should be strongly secured to prevent springing or movement in the plastered work.

Testing. When the piping is all in place, the outlets are to be capped and the whole system tested for leaks, and then accepted by the local gas company. The test consists, briefly, in attaching to one of the outlets a mercury gage, and then filling the pipes with air under pressure till the mercury in the gage stands at the height

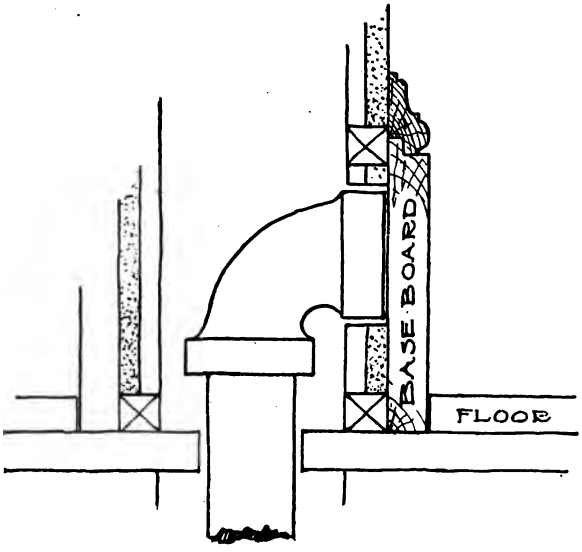


Fig. 37. Connection of Outlet Pipe with Main Pipe of Vacuum-Cleaning System

required to insure tightness, which is usually 6 to 12 inches. The apparatus is then left to stand for 10 or 15 minutes, and if the mercury at the end of the time holds the same level it is safe to say that the pipes are tight. Leaks may usually be discovered by the sound of the escaping air, but often ether is put into a cup attached to the pump and forced in with the air, so that leaks, especially in concealed parts of the piping, may be detected by the odor. Suspicion of a leak in pipe or fittings may be verified by brushing strong soap water over the place; if there is a leak, a bubble will be blown by the escaping air. Small pinholes in the pipe or couplings

may be tamped and if thus rendered tight will remain so, but pipes showing a split or large hole must be replaced.

Vacuum-Cleaning Pipes. At this time also pipes should be run for a vacuum cleaner if the system is to be installed, and in any case it is a good plan to put in a line of pipe from cellar to attic as the expense is slight and pipes run at this time can be concealed.

While portable cleaners are very efficient and easily handled, they are not so convenient as a basement machine which requires only hose connections in each story. Care should be taken that outlets are centrally located and that the outlet pipe joins the main pipe by an easy sweep, Fig. 37, and not with an elbow or T-connection. As the piping varies in detail for different machines, it is well to consider some particular make and pipe according to the manufacturer's recommendations. The methods of starting and controlling the machine from distant points should be considered, and the proper connections, electric or otherwise, installed.

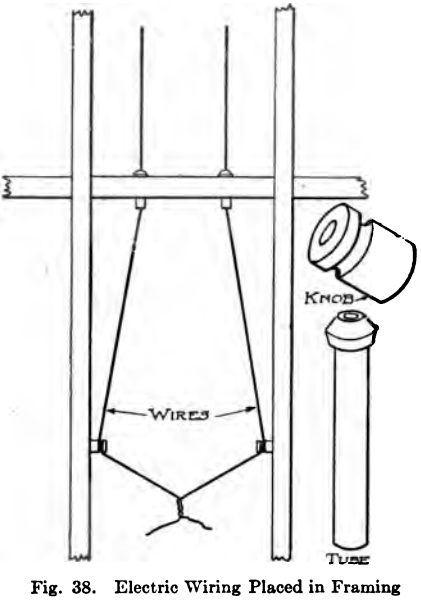


Fig. 38. Electric Wiring Placed in Framing

Electric Wiring. All country houses, unless in very remote situations where there are no chances of an electric current ever being obtained, should be wired for electric lights. There are at least three methods of installation, the usual one being the *knob-and-tube system*, in which the wires, of copper heavily insulated, are run on porcelain knobs between beams and studs, and in short porcelain tubes where passing through timbers, Fig. 38. Although the insurance exchanges employ inspectors and require that every job of wiring shall be reported to them and inspected by their men, it will be well for the superintendent to watch carefully this construction to see that all wires are thoroughly insulated and at least 3 inches apart to avoid any chance of contact; that they are not

allowed to sag; and that the joints are properly protected by a free use of insulating tape.

Upon brick or stone walls, and in all places where there is danger of injury, the *conduit* method should be used, the wires being run in conduits or pipes. In this case the angles and bends of the conduits must be made in easy curves so that the wires may be easily "drawn in".

At a cost between knob-and-tube wiring and conduit work, *duplex wiring* may be installed, in which a flexible metallic cable containing the wires in pairs and heavily insulated is used. These cables, of various makes and usually spiral in appearance, Fig. 39, unite the flexibility of the open wiring and the protective quality of the conduit, are easily handled, and assure a good quality of wire, being manufactured under the approval of the Board of Fire Underwriters. They are to be recommended for good house-wiring.

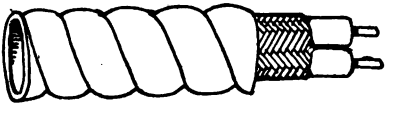


Fig. 39. Typical Armored Cable for Duplex Wiring

Metal boxes can be used to advantage at the surface, for either light outlets or switch outlets, and in many localities are required. As the position of these boxes determines absolutely the position of the finished switches and fixtures, it is important to see that they are set plumb and square with the wall and the proper distance away from rough door or window openings to clear any proposed finish. All wiring should be tested when installed and again at completion of the building, to insure against any mechanical injury.

For electric bells, it is usual to run an insulated wire secured to the studs by staples, and care must be taken to see that bells as well as light outlets are placed in convenient places. If the bells are to be operated mechanically, the manipulating wires should be run in zinc tubes; as such wires stretch and break in time, bells operated by an electric current are generally preferred.

OUTSIDE FINISH

ROOF

Before the building is ready for the plasterer, the outside and the roof must be made tight. We have seen that the gutters are set and primed or oiled to protect them against water; and above

the gutter, and rebated or tongued into the back, is set the "shingle fascia", a vertical board varying in width according to size of gutter and pitch of roof. This fascia is usually beveled off on top to receive the butts of the first course of shingles, Fig. 40.

Shingles. The shingling of the roof begins upon the fascia with a double course projecting a little, and from the butts of these shingles are measured off the courses of the roof. Unless the roof is very steep the courses should not exceed 4½ inches for the length of 16 inches, into which cedar and redwood shingles are usually sawed. Cypress shingles are found 18 or 20 inches long and are the most durable of all shingles, but redwood and cedar, especially cedar, are more commonly used. Regarding durability, cypress shingles have been known to last more than a hundred years, redwood shingles from twenty-five to fifty years, and cedar shingles from twelve to twenty years.

Fig. 40. Typical Gutter Construction

Paper. The question as to whether paper shall be put under shingles or not is open to argument. If the shingles are laid without being dipped in paint or with the butts only dipped, the paper will cause sweating, and, preventing any circulation of air under the shingles, will cause them to decay much sooner than if paper were not used; but, on the other hand, if the attic is plastered, there is, without paper, danger of damage from leaks and from fine snow sifting under the shingles. In the present case the attic is to be unfinished and we will use no paper on the roofs.

Ridge and Hips. The ridge of a shingled roof is usually finished by means of saddle boards nailed over the tops of the last courses, Fig. 41, but sometimes an ornamental cresting is used. Hips are best finished by what is called "saddle-board shingling", in which a course of shingles is put over the roof shingles at right angles with the hip. There is little danger of roofs leaking at the ridges and hips, but the hip shingles unless well nailed are likely to be blown off. The plane surface of the roof is not liable to leak, if

reasonable care is taken, but dormers, chimneys, and valleys are sources of great danger.

Flashings. The flashing against chimneys and the vertical sides of dormers is done by means of pieces of tin or zinc about 7 inches square, bent in the middle so that one-half will lie in the course of shingles and one-half turn up against the vertical wall, to be covered by the shingles of the wall or by the counter-flashing of the chimney. In the eastern States zinc is generally used for flashings, but in the West tin is the common material.

In the forming of valleys, one of two methods is followed, that of an "open" or a "close" valley. In the former case the shingles are kept apart 6 or 8 inches, and the valley is made of zinc or tin, often in long strips locked and soldered at the joints and running under the shingles from 4 to 6 inches. The defect in this method of a continuous piece of metal is that there is no chance for the metal to expand and contract in its length, without danger of straining the joints and even of starting the shingles or slates which are laid over it. For this reason the use of separate pieces of metal of the length of shingles or slates and shingled in with each course is to be preferred. These are bent, lapped in the same way as the shingles, without soldering, and are free to expand and contract without damage. In the case of the close valley, the shingles are laid very near together at the angle, and narrower pieces of zinc or tin are shingled into each course.

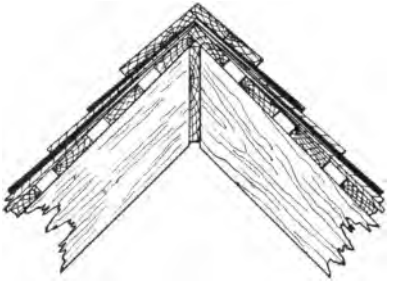


Fig. 41. Section Showing Ridge Finish

The flashing of roofs is a matter which needs a great deal of attention on the part of the superintendent, who should look especially to see that the metal used is wide enough. Counter-flashings are often omitted unless particularly mentioned. Where used, they should always be built into the brickwork if possible; if not built in, they must be carefully wedged into joints which have been raked out and pointed with cement. Every part of the flashing of a roof should be examined by the superintendent; it must never be left to the care of the builder or the workmen.

Nails. The use of galvanized nails for shingling has become general. They should be of the variety known as "cut nails" which contain a greater body of metal than wire nails and do not rust out so soon.

Slating and Tiling. With slating or tiling greater care is necessary than with shingles. Neither slates nor tiles will lie as close to the roof, or to each other, as shingles, and for this reason the boarding should always be matched, and, since the circulation of air is no object with slates, tarred paper should always be used. The lap of the slates should vary with their length, at least 3 inches for headcover being allowed; that is, each slate must lap 3 inches below the head of the second slate below it. Tiles are constructed with a variety of joints and laps designed to meet the needs of the different forms of the tile. Both slates and tiles should be put on with galvanized nails, which must not be driven too hard for fear of cracking, and yet must be driven hard enough to prevent loosening or rattling. If the cost is not too great, copper should be used for all gutters and flashings. It is a good practice to lay the first three or four courses of a slate roof above the gutter in elastic cement, and also all hips and ridges.

Fire-Resisting Roofings. The increasing demand, especially in metropolitan districts, for a fire-resisting covering for roofs has resulted in the manufacture of "shingles" other than of wood. Asbestos, tin, steel, and various types of paper coated with slag, asphalt, and other fire-resisting substances have been put upon the market. All of these aim to preserve appearance as well as to secure safety, and it is a mere matter of selection, if some other material than wood must be used. The main objection to most of these substitutes is that those of moderate cost are likely to have a rather thin appearance, or else give a metallic look which although well in itself does not generally please the taste as does the old wooden shingle.

WALLS

Window Frames. After the completion of the roof comes the preparation of the side walls for the finishing, and the first thing to be done is to set the window frames. In wooden houses the stud will usually make one side of the weight box, and the frame

will consist only of the pulley stile and casing. Sometimes the boarding is kept back from the edge of the studding, and the casing is set upon the studding with a piece of finish or a "backband" put over the joint with tarred paper or, better still, strips of zinc,

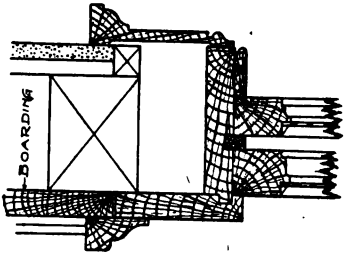


Fig. 42. Section of Window Frame Flush with Boarding

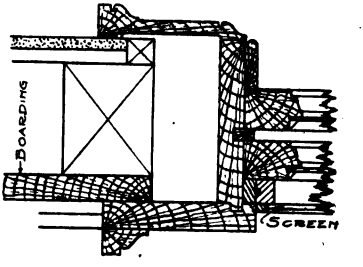


Fig. 43. Section of Window Frame Outside of Boarding

to keep out the water, Fig. 42. If the frame is set against the usual 4-inch studding, the outer casing will form one side of the groove in which the sash slides, but in the other case there is room to put a strip $\frac{5}{8}$ inch or $\frac{3}{4}$ inch wide inside the casing, in which the sashes may slide, and to leave a space for mosquito guards, Fig. 43. The top of the frame must be flashed with lead, and the bottom of the sill grooved to receive the top of the shingles or clapboarding, which are put on as soon as the frames are placed. Pockets of canvas, in which the window sill is set, are advisable in exposed situations.

Coal Chute. To avoid the marring and soiling of the cellar window frame by the putting in of coal and wood, a metal chute of stock pattern may be installed, which, if desired, may take the place of a window. It consists of a metal frame with a hinged cover which turns up entirely out of the way, disclosing a metal hopper that can be pulled forward and used as a chute for the coal, Fig. 44. If set to take the place of a window, the cover is glazed, otherwise it is better if made solid, unless the chute is in a conspicuous location.

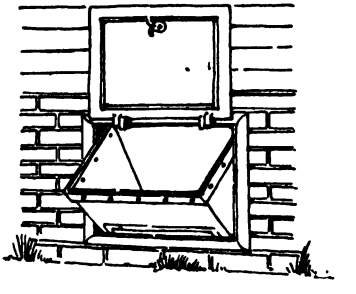


Fig. 44. Typical Coal Chute for Basement

Porch and Piazza. Before the clapboarding or shingling of the walls can be completed, the porch and piazza finish must be put up. The floors should be framed with the joists running parallel with the house walls so that the boards will be perpendicular to the walls, and the floor boards must also slope away from the house at about the rate of 2 inches in 12 feet. The tops of the piazza joists should be set about 6 inches below the main house, and it is a good plan to bevel off the tops and leave only a narrow edge for nailing, so that the water, which will run between the joints if the floor is open, will find little surface upon which to settle, Fig. 45. Sometimes the joists and girders are covered with tarred paper. The roof of the piazza, which is covered with tin, will need especial attention to see that it is given a proper pitch and that the tin is turned up against the boarding of the house wall at least 6 inches, where it will be clapboarded over. The quality of the tin should be examined, and care taken to have it painted on the underside before being laid and to have the joints well locked and soldered. Blocks must be set on the tin roof and flashed and soldered, to which the balcony posts can be secured; and where the finish of porch or piazza ends against the house, great pains must be taken to have the connection thoroughly flashed with lead.

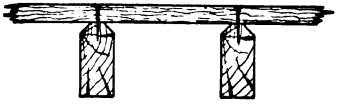


Fig. 45. Proper Construction for Piazza Joists

Clapboarding and Siding. Clapboarding is done in sections, from staging lowered successively as the work progresses. Each section is built upward from the staging, its top board being slipped under the lowest board of the preceding section, which has been left unnailed along the bottom for that purpose. The term "clapboard" in New England corresponds to "siding" as used elsewhere. Clapboards are all quarter-sawed, being cut from the log by a circular saw which cuts always toward the center; they are made 4 feet long, 6 inches wide, and ½ inch thick at the butt. Siding is of similar section but a little thicker, and is commonly sawed in the same way as boards, in lengths of 12 to 16 feet. Either clapboards or siding make a good wall covering; the best should always be quarter-sawed and laid over a good quality of sheathing paper, which is generally put on in horizontal layers, each layer being lapped

about 2 inches and breaking joints with the paper and flashings already laid.

There are many good brands of paper on the market, with very little to choose between them, the principal qualities required being toughness and soundness. A kind of siding called "novelty siding" is often used for cheap summer houses. This is nailed directly to the studding without any rough boarding, but the omission of the rough boarding, it should be noted, is always done at a great loss in strength and warmth.

Wall Shingles. If the walls were to be shingled, the same care would have to be taken as in shingling the roof, except that the shingles on the walls may be exposed 5 or 6 inches and they may be of a quality called "clears", in which the exposed lower third is free from imperfections. Shingling undoubtedly makes a warmer coating than clapboards or siding, as there are always three thicknesses of shingles to one of clapboards; but the choice between shingles and clapboards is generally determined by the character of the building and the effect desired.

LATHING AND PLASTERING

By the time that the clapboarding has been finished the inside of the house must be given over to a new set of mechanics—the lathers. The trade of lathing, although a wood-working trade, is in most localities distinct from the trade of the carpenter, and the lathers will come to the building to put on laths and for nothing else. For this reason it is well for the superintendent to see personally that all of the furring has been completed and completed properly. Walls, ceilings, and soffits should be carefully examined to be sure that their surfaces are true, level, and plumb; chimney breasts and projections of all kinds tried with a square to be certain that all angles are true; corners examined to see that nailings are provided where the laths are to make an angle; and grounds and corner beads set wherever necessary for nailings or for a finish.

Corner Beads. The use of corner beads is a matter of custom, being general in New England and less frequent in the West. In recent years the use of metal corner beads has become common, and they are to be preferred where a sharp corner is desired. Either wood or metal corner beads should be used, as they mean a

saving of time to the plasterer, and, being set and rigidly secured by the carpenter while furring the house, insure a plumb and square corner. The superintendent should see that all beads are in one length, and that they are set plumb and square. Especial attention must be paid to arches, since the perfect shape of the arch is determined by the accuracy of the beads, and it will be difficult to remedy any defects after the plaster has been applied.

Lathing. When the superintendent is satisfied that the rough work has been put in place correctly, the lathers are set to work. It is well to visit the building before much of the lathing has been done, to see that the laths are given the requisite number of nailings and are spaced properly. Three-eighths of an inch apart is the right width, but there is generally a tendency to put them too near together, in which case the mortar will not press through and form a sufficient key. If the laths are spaced too far apart, the wet mortar will not sustain its own weight. The matter of breaking joints is also of importance, the usual way being to break joints every sixth course, *A*, Fig. 46, but a better ceiling is obtained by breaking joints at every lath. Over door and window openings the laths must extend at least to the next stud beyond, to prevent cracking, *B*, Fig. 46. The direction of the laths must never be changed, and this is a point which will need to be remembered, as there is a great temptation to fill small spaces which occur with laths running diagonally and even at right angles to the other lathing, *C*, Fig. 46. This must not be allowed, as cracks are sure to appear where the change in direction occurs. The laths themselves should be well seasoned and free from large or black knots, bark, or stains. Bark, which is usually found on the edges, is a serious defect, and any laths showing this should be

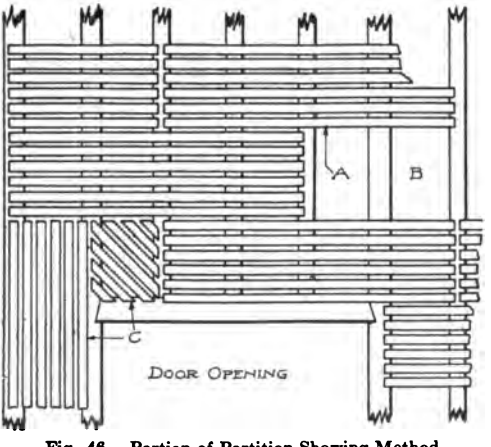


Fig. 46. Portion of Partition Showing Method of Lathing

pulled off and fresh laths placed, as the bark will invariably cause a stain in the plaster.

Metal Lathing. The use of metal laths is continually increasing and should be encouraged even for wooden houses. This form of lathing holds the plaster more firmly and is not so likely to crack or sag, and it is almost impossible to detach it even if soaked by water. Added to this are the fire-resisting qualities, which render its use advisable for the soffits of stairs in public buildings, under galleries, and over all hot-air pipes enclosed in partitions. Metal laths should always be used where wooden walls connect with brick walls or chimneys; and wherever a solid timber of any size is to be plastered over, a strip of metal lathing covering the timber and lapping well on to the adjoining wooden laths will tend to prevent cracks which would occur if wooden laths only were used. Lathing for exterior plastering should be galvanized or painted, and furred at least $\frac{7}{8}$ inch from the boarding.

Plaster. With the completion of the lathing the house will be ready for the plasterer. Already the mortar will have been mixed, and, piled in large stacks, should have been standing for a week or more. The sand and lime having passed the same scrutiny and tests which we employed when making the mortar for the mason work, the only thing necessary is to see that the mortar is well mixed and tempered and that hair of the proper amount and quality is added at the proper time.

Mixing. For the best results, the lime should be thoroughly slaked at least twenty-four hours before adding the hair, which must be thoroughly beaten up and mixed with the lime paste, and the necessary amount of sand added. This mixture should then be stacked outside of the building as long as possible before being used; for our building, at least ten days. When ready for applying, small quantities of this mixture are wet with water to the proper consistency—*tempering*, this is called. Unless particular care is taken, the sand and hair will be added as soon as the lime is slaked as it is much more convenient to do; but this should not be allowed, as the lime does not always get wholly slaked and the steam and heat of the slaking lime will burn the hair and destroy its strength. Another practice which should be avoided, is that of mixing the mortar in the basement of the building, for the steam and moisture will pene-

trate to all parts of the building at a time when the immediate application of the plaster gives no opportunity for drying off.

With regard to the proportions, about 1½ bushels of hair and 3 barrels of sand to 1 cask of lime is a good ratio, but the amount of sand will in ordinary cases be determined by the judgment of the mixer, who should be a competent and experienced man.

Applying. When the mortar is ready for putting on the laths, we must see that the first or scratch coat is well troweled to push it through the spaces between the laths so as to form a good key. In ordinary two-coat work, this first coat is put on thick enough to come within ⅛ inch or less of the face of the grounds and beads, as the finish or skim coat is merely a thin veneer of lime putty and fine white sand, troweled and brushed to a hard surface. In three-coat work, the first coat is put on about ¼ inch thick, and when somewhat hard it is scratched with diagonal lines nearly through to the laths. As soon as this coat is dry, the second coat is applied and brought to a plane with all angles and corners true and plumb. On large surfaces or in important work this is best done by running screeds, which are strips of mortar 6 to 8 inches wide and 3 or 4 feet apart, carefully laid and leveled and plumbed, with corners and angles made true and brought to the line of the second coat, which is filled in between these upon the scratch coat and brought to a line by running straightedges from screed to screed. Upon this second coat is applied the third or finishing coat, usually either the skim coat used in two-coat work, or a white coat made by mixing plaster of paris and marble dust with the lime putty. If a rougher finish is desired, as for frescoing, a coarse sand in greater quantities may be mixed with the lime putty and floated with a pine or cork-faced float. By consulting the specifications we find that this finish is called for in two-coat work to be left "medium rough".

Screens for Protecting Plaster. Before plastering is begun, the windows must be closed in with screens of cotton cloth tacked upon wooden frames made to fit the window openings. These are not only to protect the plastering from freezing, which completely ruins ordinary lime mortar, but also to prevent the unequal drying of the finished walls, which will occur near the windows in breezy weather.

Exterior Plastering. Cement plaster as a covering for exterior walls—generally called stucco—is being used to an increasing extent

in the United States. It is put on over the boarding by furring off with $\frac{7}{8}$-inch wood strips or iron rods, or it may be applied directly to the studding; wire or other metal lathing should be used in either case, and it is best to have it galvanized or painted. The plastering should be three-coat work, with one-third of Portland cement for all three coats, the last containing the coarse sand or gravel if a rough finish is desired. If metal lathing is not easily procured, a good result is obtained by lathing upon the boarding diagonally with $1\frac{1}{2}$-inch spaces and repeating the lathing diagonally in the opposite direction, all well nailed and secure. Upon this we may plaster as upon the metal lathing.

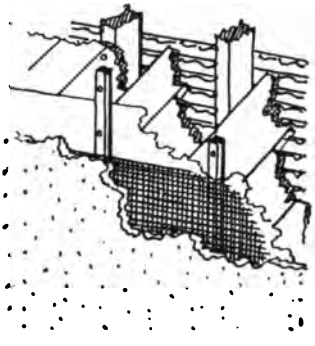


Fig. 47. Furring for Metal Lathing on House Boarding

The framing studs should be set 12 inches on centers and, so far as possible, should run from sill to plate with no horizontal timbers to cause shrinkage. This frame should be rigidly braced to avoid cracking the finish. If house boarding is used it should be in narrow widths, from 6 inches to 8 inches, matched and laid diagonally, with two nails to each stud. Waterproof paper should be laid over the boarding, well lapped and tacked, and upon this paper vertical furring strips of wood or metal are placed to receive the metal lathing, Fig. 47. These strips should be placed not more than 12 inches apart and preferably upon the direct line of the studs of the frame. Upon these furring strips the metal lathing is secured in horizontal strips, doubled at corners or reinforced by a strip of metal lath, bent and applied over the lathing. If house boarding is not to be used, the lathing may be stapled directly to the studding, Fig. 48, or, better, the metal may be fastened over quarter-inch iron rods or crimped metal stapled to the studding.

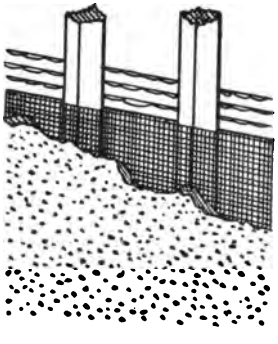


Fig. 48. Furring for Metal Lathing on Studding

Upon the lathing three coats of strong Portland cement mortar

are applied, finished with a troweled surface if a smooth effect is desired; or the finish may be of any degree of roughness, from a sand-floated surface to the extreme of roughness produced by throwing a strong mixture of cement and sand or wet pebbles against the finishing coat. It is also possible to apply the mortar by means of a machine which is made for the purpose.

In case no boarding is used, a heavy coat of mortar should be applied to the back of the lathing thus completely bedding it in mortar and forming a thick wall partly between the studs, in which the metal lath acts as a reinforcement, while the whole tends to stiffen the frame to a great extent, Fig. 49.

A coat of plastering is an excellent treatment for the exteriors of old wooden houses. When an old house is to be covered, every part should be thoroughly examined and treated according to defects which may be found. Leaks in roof or gutter which will admit water back of the mortar coat must be repaired, loose clapboards or shingles secured, and window casings examined and treated according to taste and judgment as to whether they should show outside the coating or should be covered. Good results are often obtained, if the clapboards or shingles are sound, by stapling the metal lathing directly to the face of butts, the serrated space behind giving a key; but a safer method is to fur vertically with wood or metal.

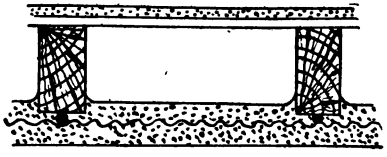


Fig. 49. Backing Coat of Plaster Where Boarding Is Not Used

Concreting the Cellar. When the last of the inside plastering has been completed, the concreting of the cellar should be begun so that it may be drying out with the plastering. For this the best cement must be used, mixed in proper proportions, puddled, and troweled to a perfectly level surface. A good mixture for cellar concreting is 1 shovelful of Portland cement, 3 of sand, and 6 of broken stone or screened pebbles, with a top dressing of cement and fine stone from which the dust has been screened.

Waterproofing. If the house is located in an especially wet place, it may be necessary to use other than the ordinary means of a well-built wall and strong concrete floor to withstand the pressure which ground water sometimes exerts against the cellar. In this

event a waterproofing compound must be combined with the cement, and in extreme cases a lining of tarred felt should be used, mopped to the outside of the walls and previously run under the wall on top of the footing, Fig. 50, to be continued over the whole cellar bottom on a rough bed of concrete. This surface is then mopped with pitch and over it is laid the finished concrete of the cellar.

Fireplaces. While the plastering and concreting are drying out, the fireplaces are usually finished. These are to be of bricks and should be built with a splay of from 6 to 8 inches to the sides. (See Fig. 36.) The back lining is built up plumb for about six

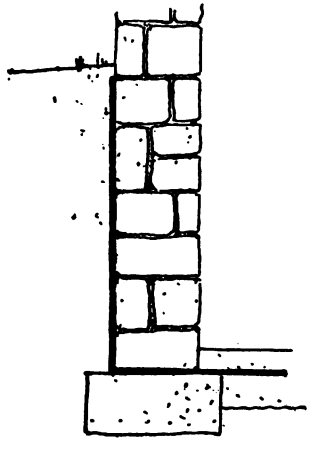


Fig. 50. Section of Cellar Wall Showing Method of Waterproofing with Tarred Felt

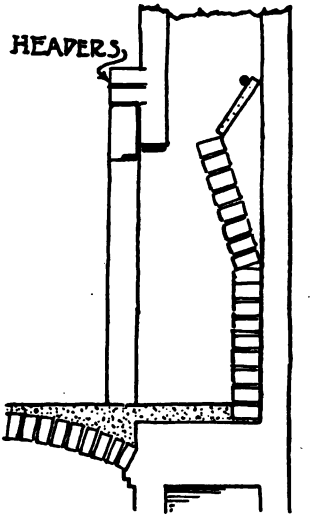


Fig. 51. Section of Fireplace Showing Construction

courses and then inclined toward the front until an opening of about 2 inches only is left, Fig. 51. If a flat arch or level bricks are used for the opening there should be provided a wrought-iron bar or, better, two bars, which must be let up into the underside of the bricks so that they may not be seen. Care must be taken to see that fireplaces are set in the exact center of chimney breasts and rooms; also that the faces of the bricks are in the required position, usually flush with the plaster line, although this may be varied to allow for differences in the form of mantel desired.

Dampers and Throats. Cast-iron dampers and throats for fireplaces may be bought and set into place, the commonest type being the *tip-and-slide* damper, Fig. 52. This consists of an iron frame containing a sliding damper for use if little draught is required, the entire inner section tipping back to open the whole width of the fireplace. Care should be taken that the flue is not drawn in so quickly that there is not room to tip the damper, and that the damper is set high enough so that the usual hanging toggle does not show. More complicated dampers have the opening and closing controlled by a rod connecting with a milled head or thumb piece on the surface, and so-called "throats" combine the damper with a short upstanding or slanting duct to connect with the flue.

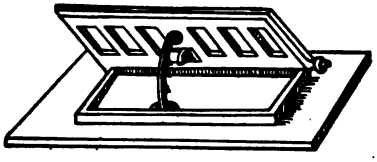


Fig. 52. Tip-and-Slide Damper for Fireplace

PLUMBING

PIPING

Soil Pipes. As soon as the plasterers have removed their stagings from the house, the plumber can at once complete the piping. In some cases it will be necessary to run the main soil pipes concealed behind the plaster, but it is much better if they can be in plain sight. Extra heavy pipe is called for, to be plain and painted on the outside with red lead. These pipes should be tested for sand holes before delivery; since they are plain, any imperfections in the casting may be readily seen; this would not be the case if the pipes were asphalted, as they usually are. The joints of the soil pipe will need special watching to see that they are not slighted in any way. All the joints must be made of oakum, driven in tight, and finished with melted lead which will be poured around each joint and then thoroughly calked after the pipes are in position, Fig. 53. It is never advisable to complete the joints before securing the pipes in place, for the jar of this handling may loosen the lead. The pouring-in of melted lead will not secure a tight joint as the lead shrinks away upon cooling and it is necessary to force it again into contact with the pipe. This is the object of calking, and if well done the lead in the joint will show marks of the iron all around.

Lead Pipes. Lead pipes will be most easily examined on delivery, when the ends of the coil will be stamped with some figures or letters to denote the weight per foot. After the pipe has been cut it will be next to impossible to tell by appearance whether or not it is the right weight. All lead pipe which is not new or which shows unequal thickness should be rejected. The running of lead pipes must be carefully watched and boards should always be put up, against which or upon which the pipes may be securely fastened. Lead pipes which are run vertically should be fastened by hard metal "tacks", which are soldered to the pipe at intervals of about three feet. Unless this rigid fastening is made, the pipes will "crawl" and droop because of alternate contraction and expansion. Horizontal pipes may be secured by bands but should have a continuous strip of wood to support the entire length, or they will in time sag and form a hollow place, from which the water cannot be drawn when pipes must be emptied. The pipe should be made to rest upon the straight support and never be allowed to take an upward bend in its level course, as this soon becomes filled with air and would eventually stop the flow of the water unless punctured at the highest point.

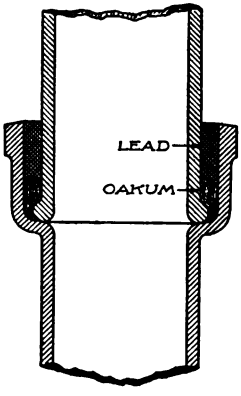


Fig. 53. Section Showing Joint of Soil Pipe

All the joints in lead pipes should be wiped joints, as specified, and no cup joints, which are more easily made but are not so strong, should be accepted. The joining of lead and iron pipes must be made by wiping to the end of the lead pipe a strong brass ferrule which can be calked into the iron pipe. The superintendent must watch carefully to see that this is done for it is a great temptation to many plumbers to putty the lead pipe into the socket of the iron pipe.

Brass Pipes. For a hot-water system, brass pipes should be used since they are not affected by the alternate warmth and chill of the water which would cause lead pipes to sag between the supports. Indeed, if the additional expense is not too great, it is worth while to make all the supply pipes of brass, which can be obtained either plain or coated inside with tin. If brass piping is used, it

must be put up so that the angles and bends are free to move a little, or else the expansion and contraction will strain the fittings and produce leaks. The effect which the water will have upon the pipes is a matter which should be considered, but it can be determined only by local examination, and recommendations as to the use of piping must be made with reference to the analysis of the local water supply. If brass piping is used, it should be semi-annealed and specified as "iron size"; that is, the thickness must correspond to that of iron pipe of similar size, as distinguished from so-called "plumbers' tubing", the use of which is not to be recommended.

Iron Pipes. If the cost of brass piping proves to be excessive, a good quality of iron pipe may be substituted where there is danger of the corrosion of lead or of its bursting by great pressure. Iron pipe may be obtained with a lining of block tin, which forms a pure and very satisfactory channel, or with a less expensive galvanized or zinc coating. The directions given for piping with brass must also be followed in running iron pipe, and, besides, precaution must be taken against condensation which will take place upon iron pipes in warm weather, because of the fact that iron conducts heat so rapidly. This condensation may be so great as to trickle down and cause damage to paper or decorations. Where there is this danger, the pipes should be run in tubes of zinc which will conduct the water to a safe outlet. This precaution should be observed, even in the case of lead or brass piping, when costly decorations or papers are liable to injury from bursting or leaking pipes.

General Rules for Running Pipes. The fastening and joining of all pipes should be carefully watched to see that they are run in straight lines, with free angles. The hot-water pipes should be separated by a little space from the cold-water pipes so that there will be no transmission of heat from the former to the latter. Every pipe must be run so that it will pitch toward one of the faucets or waste cocks, which must be provided in convenient places and in sufficient numbers to shut off and drain both the hot- and cold-water pipes of any given part of the house, as well as of the whole system.

Waste Pipes and Traps. The waste pipe or outlet of every plumbing fixture must have, as near as possible to the fixture, a trap to prevent foul odors and sewer gas from escaping. The simplest form of trap, and in its improved form one of the best, is the S-trap,

Fig. 54. This consists of a piece of pipe bent into the form of the letter **S**, with a screw in or near the bottom to permit cleaning out. The theory of this trap is that some of the water which passes through will remain in the trap, as shown in the cut. In actual use, however, if sufficient water runs through to fill the outlet completely, the falling water will create a vacuum at *A*, which will cause the outside air to force out the water in the trap until it falls below the bend *B*, and will thus destroy the seal. A greater danger exists where two or more fixtures are connected with the same soil pipe. In this case, the seal of the lower fixture will be broken by reason of the column of water discharged from the upper fixture. A partial vacuum is created in the soil pipe, and the outer air, rushing in to fill the void by the easiest way, will force the water out of the trap below, Fig. 55. This is a real danger and should be guarded against.

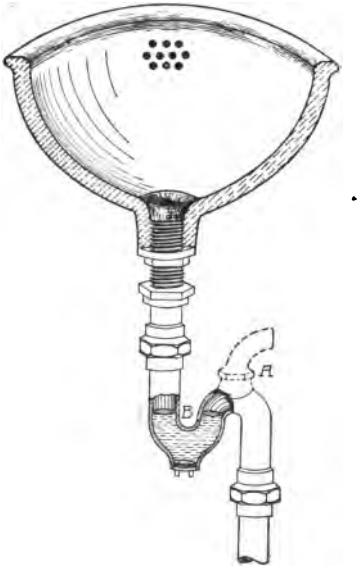


Fig. 54. Section of Plumbing Showing Use of S-Trap

The improved trap which obviates these perils has an inlet at the highest point of the trap, *A*. The vacuum in the outlet pipe will be filled from this source without disturbing the water in the trap. This inlet pipe must, of course, be carried to some main air pipe; it is therefore, customary to run beside the main soil pipe a line of vent pipes to which the different trap vents are attached, the main vent usually starting from the base of the soil pipe and entering it again above the highest fixture.

Another way of guarding against siphonage is to make the trap so large that enough water will drain back from the outlet and sides of the trap to restore the seal. This is called a "pot" or "cesspool" trap. City plumbing laws generally require the venting of traps, and it should be done in all cases.

Testing. When the waste and air pipes are all in place and the connections for the various fixtures are put in, the whole system

should be subjected to an effective test. The simplest and most efficient one to employ at this stage is the water test called for by our specifications, which should be carried out in the presence of the superintendent. It consists in closing all openings in the pipes and filling the whole system with water, either by attaching a hose at the bottom or by filling from the top. If the water does not lower in the pipe after standing ten or fifteen minutes, the system may be pronounced tight. If, however, the water level drops, there is evidently a leak somewhere which must be sought out at once. In a tall line of piping the water pressure will be such that defective joints or sand holes will be discovered by a stream of water, or at least by the trickling of water down the pipe. Imperfect joints in the cast-iron pipes may be remedied by more careful calking, but sand holes cannot be repaired. The defective pipes must be replaced, and the new pipes again tested until the system proves absolutely tight.

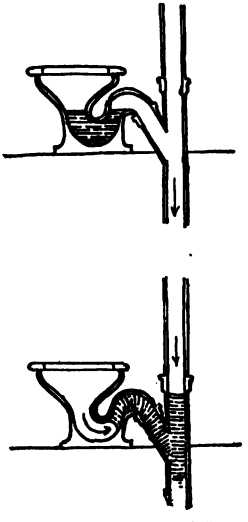


Fig. 55. Siphonage of Trap

After all fixtures are set and all connections completed, another test is usually made. This may be the "peppermint test" or the "smoke test". In the former a vial of oil of peppermint, which is sold sealed for the purpose, is taken to the roof and emptied into the top of the soil pipe. A quantity of hot water is immediately poured in and the top of the pipe closed by stuffing in paper or rags. The vapor, charged with the odor of peppermint, is thus unable to escape and will penetrate the whole system. All drain, air, or waste pipes, and connections are immediately examined and any odor of peppermint detected will be evidence of a defect which must be remedied. Great care must be taken in applying this test. It should be made by separate persons, one outside and one inside the house, and no direct communication should be held until the test is pronounced satisfactory.

Another method of applying the peppermint test is to close all vent pipes and vaporize the oil of peppermint in the receiver of a small air pump, and then to force the vapor into the system under

pressure. The receiver is provided with a gage so that any leak will cause a fall in the mercury and can then be located by the odor of the peppermint.

The smoke test is required in the building of our house. This is made by closing the system as for the peppermint test and forcing into the pipes, by means of a bellows, smoke from oily waste or some similar substance. When the pipes are filled, a slight pressure is produced, which is shown by a float that rises and remains in this position if the joints are tight. If there is a leak, the float falls as soon as the bellows are stopped, and the leak may be located by the issuing of smoke from the joint. Special machines are to be bought for making these tests, which should be carried out in the presence of the architect or superintendent.

HOT-WATER SUPPLY

Attic Supply Tanks. In New England it is customary to supply the bath boiler from a separate tank in the attic, this tank being filled from the regular house service with a ball cock to regulate the flow. The supply from the boiler to the various fixtures is made to return again to the boiler for circulation, which allows hot water to be drawn at once at each fixture. From the highest point of the circulation a small "expansion pipe" is run to the tank and turned over the edge to discharge just above the water line, in order to allow the steam and froth from the boiling of the water to escape into the tank. This tank should be supplied with an overflow to some convenient fixture. Outside of New England, the tank is generally omitted and the boiler filled from the house system, but this requires a strong boiler, usually of galvanized iron, and is not so satisfactory as the expansion system.

Range Boilers. Hot water is usually provided for by connecting the boiler to a water back or heating coil installed in the fire box of the kitchen range, the supply of hot water depending upon the use of the range for cooking purposes. Another method is to install the boiler in the cellar and to connect it with both the furnace and a separate heater. In this case, the continuous furnace fire in cold weather keeps a constant supply of hot water during the winter months, and the piping is so arranged that when warm weather

comes, the furnace can be disconnected and the separate heater used as needed.

Range boilers are made of copper or of plain or galvanized steel, and they may be set vertically or hung horizontally, as the location requires. The most common type is the vertical boiler of from 30- to 60-gallon capacity, set on an iron stand beside the kitchen range, and connected to a cast-iron water back or a pipe coil in the range, Fig. 56. The cold-water supply is piped into the boiler at the top; it discharges near the bottom of the boiler, and passes thence into the water back; there it is heated and returned, either to the boiler by a pipe higher up, Fig. 57, or sometimes to the outlet pipe above the top of the boiler.

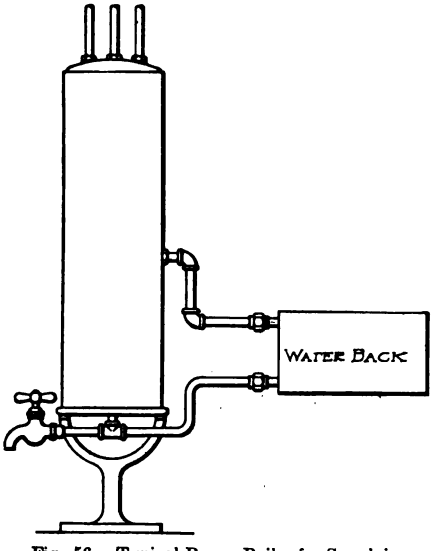


Fig. 56. Typical Range Boiler for Supplying Hot Water

Gas Heaters. Where gas is available for heating, one of the various forms of gas heaters may be employed, either alone or in connection with the range, furnace, or other coal fire. The simplest type of heater keeps an ordinary gas flame burning all the time if a constant supply of hot water is desired; or, if the hot water is wanted only periodically, the flame may be extinguished and relighted, as occasion requires.

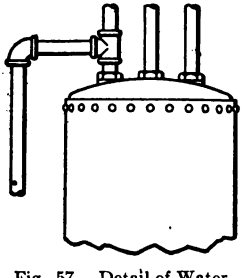


Fig. 57. Detail of Water Tank Showing Connections

Other types contain automatic devices for regulating the size of the flame according to the use of the water. These heaters usually have a small pilot light which burns when water is not being heated; and the pilot light and burners are so arranged that the opening of a faucet in any part of the hot-water system releases a pressure which opens the gas valve, and lights

the burners. When the water has reached the proper temperature and the faucet is closed, this operation automatically shuts off the burners, thus giving a flexible and inexpensive system.

Instantaneous Heaters. Another device is the instantaneous heater, a small appliance which may be placed at the point where hot water is to be used. It consists of a coil of brass, copper, or some other good conductor, through which cold water from the main is made to pass slowly, subjected to direct contact with a range of gas flames, Fig. 58. These burners are ignited from a small pilot light which is swung into contact when hot water is required.

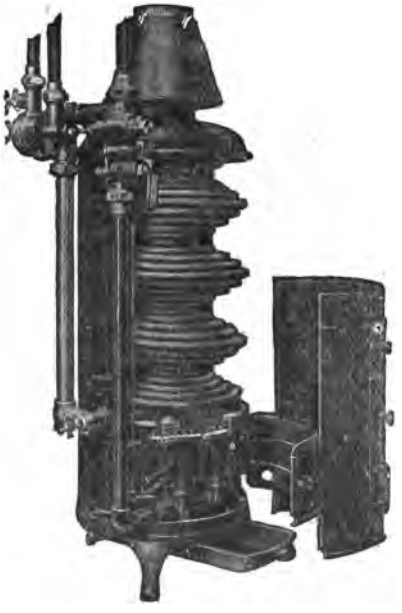


Fig. 58. Part Section of Instantaneous Gas Heater
Courtesy of The Humphrey Company, Chicago

PRIVATE WATER SUPPLY

Compression Tanks. Where no public water service is available, a private supply becomes necessary. This may be secured by sinking a well and installing a compression tank in some convenient place to be filled by a hand or power pump. The pump forces the water into an air-tight tank until the air is compressed at one end to a considerable degree. The objection to a hand pump lies in the fact that it is necessary to keep the tank reasonably full to maintain the pressure, and the task of keeping it filled is a good deal of a nuisance, to say the least. A much better way is to install a pump deriving its power from electricity or gas which can be more or less automatically controlled, thus relieving the owner of the bother of watching the compression.

Special Systems. Other systems for the delivery of water under pressure are to be found, varying principally in adaptation, and most large firms handling pumps are ready and willing to make recommendations to fit particular cases.

PLUMBING FIXTURES

Water Closets. The standard fixture consists, in general, of a closet in one piece, supplied by a sure and quick flow of water, and emptied by a simple and ample discharge. The superintendent should see that the quality and pattern are as called for by the specifications, that they are perfect in every respect, and set up in a workmanlike manner.

Types. There are several types of closets from which to choose. The simplest of these is the *short hopper*. This consists of an earthenware bowl, Fig. 59, and a trap, the latter being sometimes made of earthenware and sometimes a lead or iron trap to which the bowl is bolted, Fig. 60. The contents are washed into the soil pipe by a discharge of water all around the top rim, which is curled over and perforated or brought to a narrow opening. An improvement of this form is the familiar pattern known as the *wash-down* closet, in which a deeper trap and a larger water area is formed than that made by the regular hopper and trap. This closet requires a large flush of water to remove the contents and is somewhat noisy. To overcome this and to assist in the discharge as well, the plain siphon type, and the siphon jet type, Figs. 61 and 62, have been designed. In this closet a small inlet in the bottom of the basin is connected with the flush pipe, so that when the bowl is flushed a jet of water is projected upward, which assists in removing the contents of the basin and also in filling the outlet. The latter is contracted somewhat in order that the flow of water may fill it completely and produce on a large scale the vacuum previously described in connection with the S-trap, so that the pressure of the air upon the water in the basin helps to push out the contents. An

Fig. 59. Simple Iron Hopper
Courtesy of Crane Company, Chicago

objection to the jet is found in houses which are to be left unoccupied during the winter, since the water which is to be thrown out

Fig. 60. Oval Flushing Hopper with S-Trap
Courtesy of Crane Company, Chicago

to form the jet remains in the bowl, even when the trap has been emptied, and requires especial attention to avoid being frozen.

Another form of siphon closet produces the siphonic action without the jet by making a sudden turn in the outlet pipe, which causes the flush of water to fill the pipe completely and to produce a vacuum with the same result as described. A type of closet called the *washout* closet was formerly much in vogue, Fig. 63, but it is not so positive in its action as the others and is less popular than formerly.

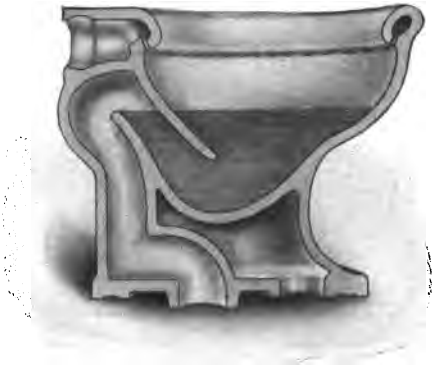


Fig. 61. Section Showing Typical Siphon Closet
Courtesy of Crane Company, Chicago

Connections and Vents. Close attention should be paid to the connection between the closet and the soil pipe, since this connec-

tion, except in the case of the hopper closet with metal trap, will come on the sewer side of the trap and must be made absolutely tight. Some of the best closets are constructed so that the connection shall be under water and any leak will at once betray itself.

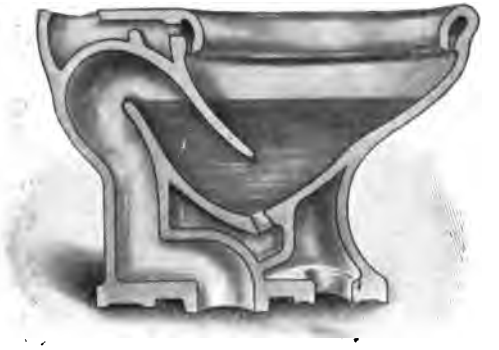


Fig. 62. Section Showing Typical Siphon-Jet Closet
Courtesy of Crane Company, Chicago

Another patented connection retains about a pint of water in a ring where the connection is made, which will appear upon the floor if the connection is not perfect. The connection from this point to the soil pipe is usually made with a lead bend, calked, by means of a brass ferrule, into the soil pipe.

All closets should be provided with a "local vent" outlet, a tube which extends from the upper part of the basin and to which a galvanized pipe may be attached and carried to the nearest warm flue for the ventilation of the basin; all traps, especially where the discharge of higher fixtures may create a vacuum in the soil pipe, should be vented to the main stack of vent pipes.

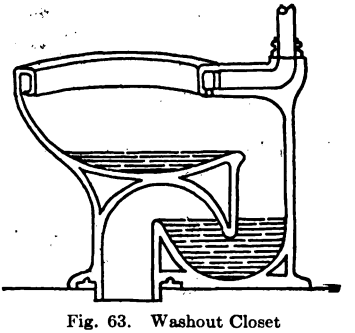


Fig. 63. Washout Closet

Tanks and Flushing. The usual way of providing for a sure supply of water to flush out the closet has been to fit up over it a copper-lined tank supplied from the house service and regulated by a ball cock. The operation of flushing the closet is performed by pulling a chain or rod which raises a heavy plug from the upper end

of the flush pipe and causes a more or less prolonged flow of water, when the plug again seats itself and the tank is refilled, Fig. 64. This operation, simple in itself, is productive of considerable noise, and there are on the market many devices aimed to secure an ample flow with a minimum of noise. Another form of tank, and one especially valuable where height is limited, is called the *low-down* tank, Fig. 65, in which the loss of power of gravity is made up by enlarging the supply. These are very satisfactory in their operation.

Fig. 64. Elevated Tank for Flushing Closet
Courtesy of Crane Company, Chicago

A newer and increasingly popular form of flushing closets is by means of a valve, Fig. 66, which delivers water directly from the general service, or from a special supply, and then closes automatically. These valves are put upon the market by different dealers under various names, but are all nearly identical in principle. They were formerly installed where many closets were to be supplied or where the presence of any kind of tank was undesirable, but they are coming more into favor for general usage and are called specifi-

Fig. 65. Flushing Closet with Low-Down Tank
Courtesy of Crane Company, Chicago

cally *flush valves* or *flushometers*. They have the advantage of doing away with the separate tank for each closet. The action consists in depressing or lifting the lever, *A*, Fig. 66, which permits the flow of sufficient water to flush the closet properly, and then closes automatically, causing very little noise. To insure a good flow when flush valves are used, a larger pipe must be run than is required to supply a tank. Some of these valves are operated by the pressure of the flow of water in the pipes upon the valve, others by a spring control

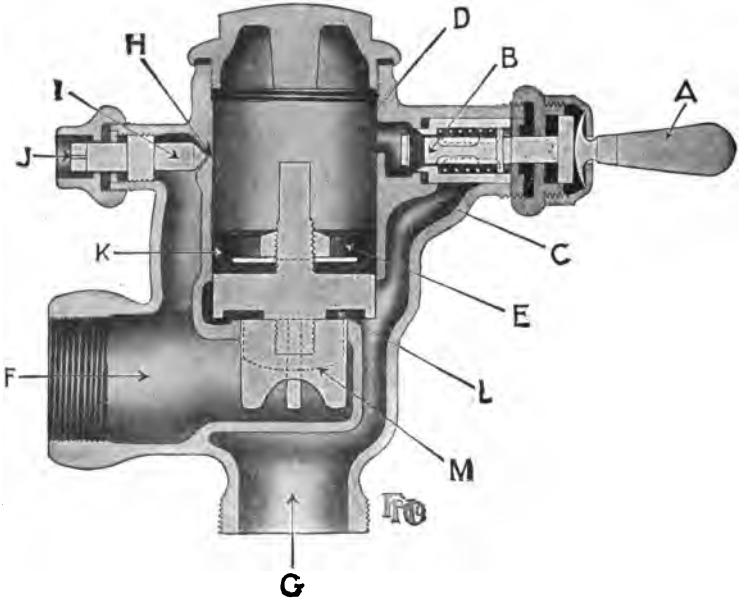


Fig. 66. Section of Boyle Flushing Valve. A—Oscillating Handle; B—Release Stem; C—By-Pass; D—Cylinder; E—Piston; F—Water-Way to Valve; G—Water-Way to Closet; H—By-Pass; I—Regulating Screw; J—Loose Key; K—Leather Washer; L—Leather Seat Washer; M—Refill Disk

Courtesy of Federal-Hueber Company, Chicago

operating noiselessly in an oil chamber, and both kinds can be regulated to give as much or as little flow as is desired.

When this form of flush is under consideration it should be remembered that some local plumbing ordinances do not permit the use of these valves when applied directly to the main supply, but require that a separate tank supply be provided.

Lavatories. Not so much choice is to be found in the selection of bowls and tubs. In the former the main differences are to be

found in the overflow and waste. These appliances have advanced from the old-fashioned plug and chain, Fig. 67, to the most advanced form of outside connections, Fig. 68, which is the pattern called for by our specifications.

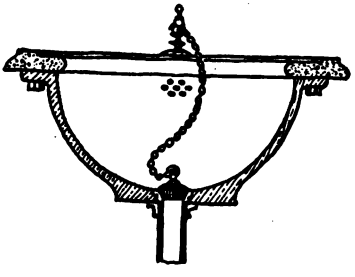


Fig. 67. Section of Lavatory Bowl with Plug and Chain

Pedestal Fixtures. Of greater attractiveness but more expensive than others are the large lavatories which are supported by means of legs or pedestals, the legs being the first deviation from the wall supports and

Fig. 68. Modern Lavatory with Outside Connections
Courtesy of Crane Company, Chicago

the pedestal a later form, of better appearance, Fig. 69. These are particularly adapted for use in the modern tiled bathroom where no

backpiece is needed. The bowls and tubs are made oval in shape as well as square, being set clear of the wall so as to allow cleaning all around. The pedestals are square, round, or of other shapes, and as plain or as ornamental as may be desired. These fixtures may be obtained in porcelain or enameled iron.

Fig. 69. Pedestal Lavatory
Courtesy of Federal-Hueber Company, Chicago

Bath Tubs. In the selection of a modern tub our choice may range from the ordinary roll-rim, enameled iron tub with painted exterior, which is excellent in all respects, through the various stages of finish and pattern to the solid porcelain tubs of luxurious design and finish. In form there are three general types of tub—those which stand free upon legs, those having solid bases, and those which are built into the wall on one, two, or three sides, or even, if desired, tiled across the front.

The simplest and least expensive kind is set on legs and stands free from the walls and floor far enough to allow washing under and about it, Fig. 70. The tub carried down to the floor does away with washing underneath, which is an advantage, while the tub more or less built-in requires still less attention besides giving a better appearance, Fig. 71.

Fig. 70. Typical Bath Tub on Legs
Courtesy of Crane Company, Chicago

Both porcelain and enameled iron tubs are left with

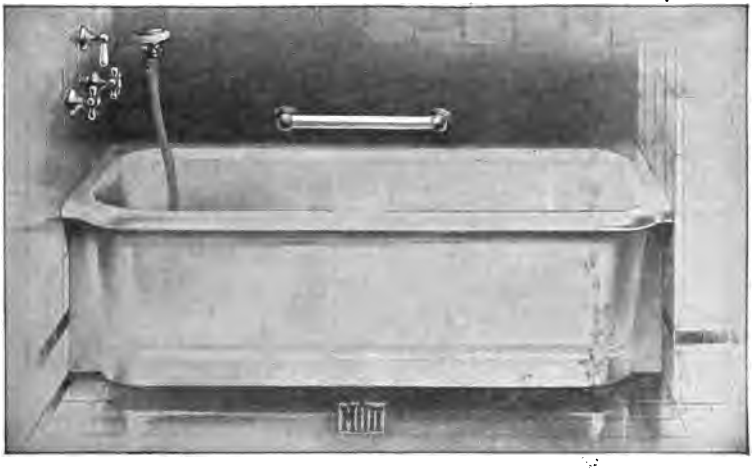


Fig. 71. Typical "Built-In" Bath Tub
Courtesy of J. L. Mott Iron Works, New York City

the outside surface rough, if they are to be covered with tiles or other finish; but if they are to be exposed, the porcelain must be glazed or given a painted or enameled finish. The best finish used on porce-

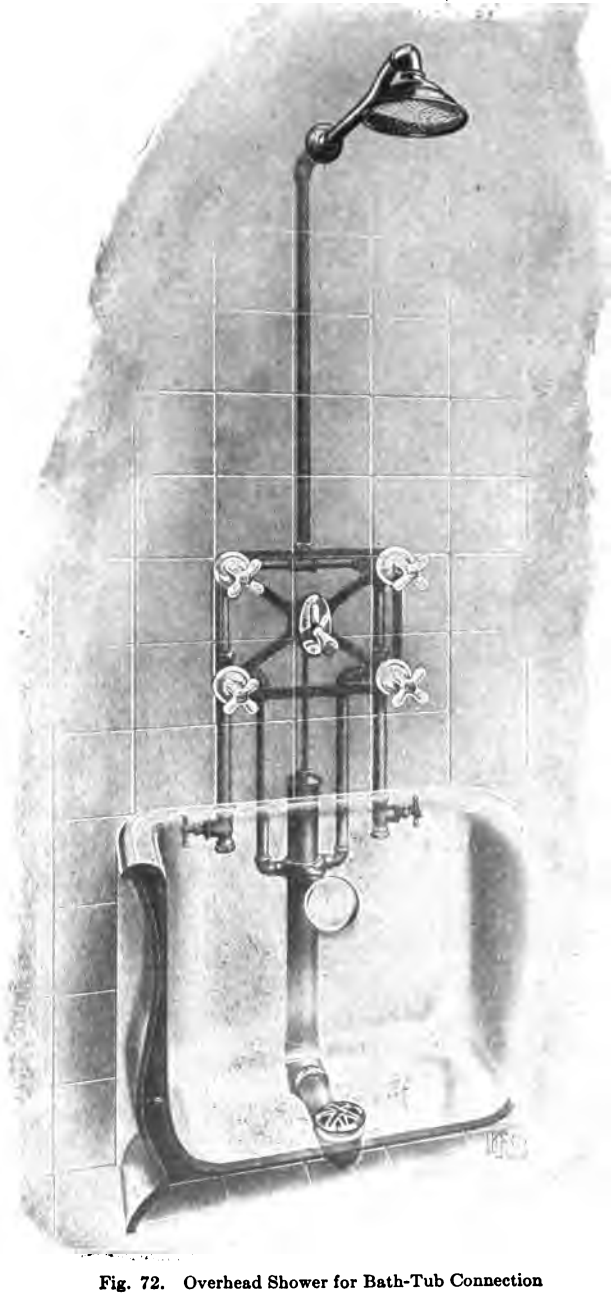


Fig. 72. Overhead Shower for Bath-Tub Connection
Courtesy of Federal-Hueber Company

lain or enameled iron is known to the trade as "No. 1 Zinc White Finish", and consists of a number of coats of enamel each baked on and smoothed down. This may be decorated with lines or patterns in colors, as desired.

Grades of Goods. Porcelain goods are marketed in two grades with considerable variation in price. "Class A" represents the highest average of production possible, "Class B", a lower average grade but one of fine quality, it being well understood that it is impossible to make large pieces of this ware absolutely perfect, that is, without speck or mark of any kind whatever.

Enameled iron goods are put on the market in two grades, the better of which represents an article thoroughly coated with enamel, applied as evenly and smoothly as the art permits, and under careful inspection during the different processes of manufacture. The second grade includes goods with a coating reasonably smooth, two or three pinholes and minute scratches or lines being allowed. Unimportant blemishes, such as small specks of foreign matter in the enamel, cannot be entirely prevented in goods of either grade.

Shower Baths. The shower bath has become a fixture of general use in the modern well-equipped bathroom. It may be installed either in connection with the tub or as a separate fixture. The simplest way is to extend the hot- and cold-water pipes of the bath supply up to a connecting valve, within easy reach, which controls the flow from a shower head set to discharge into the tub. This valve should be of an anti-scalding pattern so arranged that it is impossible to turn on hot water of an unexpectedly high temperature. A rubber or duck curtain supported from a large ring prevents the spray from splashing beyond the rim of the tub, and the water falls into the tub and drains through the regular fixtures, Fig. 72.

A separate shower—that is, one not over a tub—can be set in a corner of the room at the side, or in a niche or cabinet, receptors being made to meet all conditions. One advantage of a separate fixture, is that it permits the installation of encircling pipes giving needle-baths, liver-sprays, and a variety of showers.

Medicine Cabinets. Cabinets for medicine or toilet goods are an important feature of the bathroom. These may be finished on the outside and hung to the wall, but a better arrangement is to provide a pocket the depth of the studs and to set the cabinet in

with little or no projection. Cabinets of different sizes may be bought; some are made of wood and finished with wood, others are made with a celluloid covering over wood. The best cabinets are

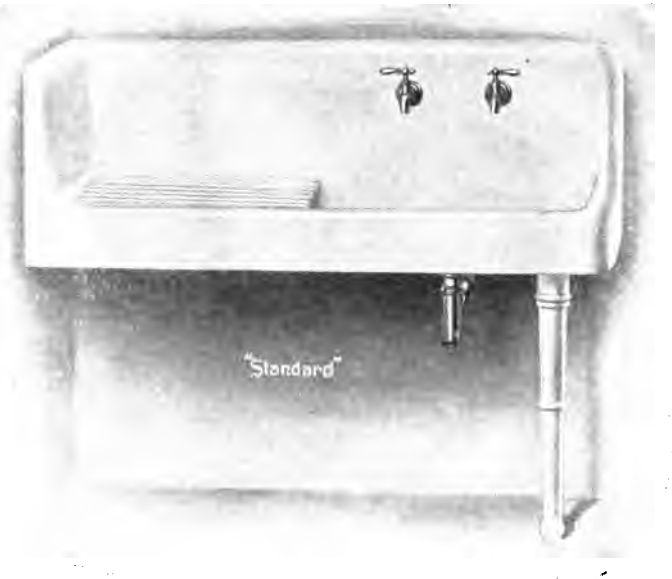


Fig. 73. Sink with Integral Back Piece
Courtesy of Federal-Hueber Company, Chicago

Fig. 74. German Silver or Copper Pantry Sink with Overflow and Waste Connection
Courtesy of Crane Company, Chicago

of enameled metal with adjustable glass shelves, and have a plain enameled door or a mirror set in the face of the door. These are usually set over the lavatory and flanked on either side by lights.

Sinks and Trays. Not the least important of the plumbing fixtures are the sinks and wash trays, which are subject to harder and more constant use than any of the others. For the kitchen sink the choice will lie primarily between soapstone, porcelain, and iron.

Soapstone sinks, although they have been the standard for many years past, are open to the objection that they present a surface slightly absorbent, which in time becomes dingy from grease and soap. *Porcelain sinks* are very satisfactory but expensive and are used only in costly houses.

In *iron sinks* the choice may be made between a plain and an enameled finish. The old style of plain iron sinks to be set in a wood frame are still on the market and are a good article. At a little more expense sinks enameled on the inside only may be obtained, but a better sink and one of increasing popularity is enameled inside and out. The best type of these is cast with integral backpiece on back and end, Fig. 73.

The pantry or "butler's" sink for the washing of dishes is best if made of German silver, white metal, or copper, Fig. 74. These sinks have a standing overflow, designed to retain a considerable depth of water so that fragile dishes can be washed conveniently and with little danger of breakage. Sometimes the sinks are made to order with a central partition giving separate compartments for washing and for rinsing, and it is possible also to have the drainboards and back covered with the same metal as the sink.

Laundry Tubs. These are made in the same range of materials as the better grades of kitchen sinks and the selection of the particular kind will depend mainly upon the location of the tubs. If the laundry is put in the basement or is a distinct apartment anywhere, a two- or three-part set of soapstone tubs is very satisfactory. If, however, as is often the case, tubs are installed in the kitchen, the style of the kitchen sink may influence the choice of the tubs.

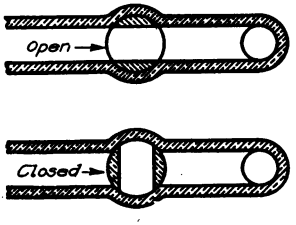


Fig. 75. Section Showing Ground Cock Open and Closed

Cocks. The choice of cocks for the fixtures will lie mainly between two kinds, the *ground cock* and the *compression* or *screw-down cock.* The former consists of a ground plug through which is

put a hole in line with the aperture; the cock is opened by turning the plug so that the hole is in the range of the bore, and closed by turning it so that the hole is across the bore, Fig. 75. Although simple and positive in action, this form of cock is open to the objections that when in constant use the plug and socket become worn, especially if the water contains any sand or grit, and if used only occasionally, the adjacent parts become corroded so that the plug refuses to turn. A better form is the compression cock, Fig. 76, in which the spindle is screwed down hard upon the opening and is given a perfect contact by means of a washer of leather or composition, which can be easily renewed when it becomes so much worn that it allows the cock to leak.

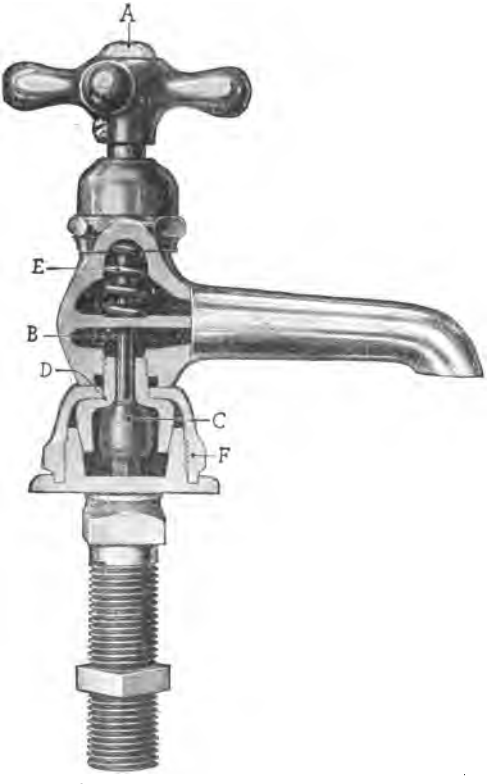


Fig. 76. Section of "Cornell" Self-Closing Faucet. A-Handle; B-Stem; C-Ball; D-Seat; E-Spring; F-Union
Courtesy of Federal-Hueber Company, Chicago

Compression cocks require several turns to seat the valves in place and are in no sense quick closing. If quick closing is desired, it may be secured by using a type known as the *Fuller cock*, Fig. 77, in which a core or plug is operated in the waterway by a quarter-turn of an eccentric stem. There is some objection to the use of quick-acting faucets if the water pressure is high on account of "water hammer", but with ordinary house pressure this is not a serious objection.

Faucets for lavatories and bathtubs may also be obtained of a double pattern that mixes the hot and cold water before it flows from the pipe. The connecting parts are sometimes visible and

sometimes concealed by the porcelain or enameled rim, the labeled handles only showing.

The cocks in bathroom and china closets should, in general, be nickel-plated, but the cocks and piping of kitchen and laundry will be more satisfactory if of polished brass. The cold-water cock of these fixtures, and of the pantry sink as well, should have a hose-nozzle termination to facilitate washing the back porch, etc.

Supervision. When the plumbing fixtures have been installed, the superintendent should see that they are properly protected from accident or abuse, until the owner is ready to assume the care of the house.

Fig. 77. Fuller Basin Faucet
Courtesy of Federal-Hueber Company, Chicago

HEATING

Systems of Heating. While the plumbing work is being done, another set of men have been putting in the heating apparatus. The selection of the heating apparatus will depend upon local custom, expense, and personal preference. Three principal methods present themselves with some special features to recommend each. These are the hot-air furnace, the hot-water heater, and the steam boiler. The simplest and least expensive to install is the hot-air furnace, Fig. 78, which also has the merit of introducing a continuous supply of warmed fresh air into the house, thus improving the ventilation. Next in cost of installation, is the system of direct steam heating; when once installed, the cost of maintenance is less than the hot-air furnace. This is due in part to the fact that in direct steam heating, the already tempered air of the rooms is simply raised to the desired warmth, and fresh air must be supplied by other means. The system has the advantages of being more easily adapted to the heating of distant parts of the house, and of being positive in its action at all times.

Of greater cost to install, but with some advantages in maintenance, is the system of direct hot-water heating. This is similar to direct steam except that hot water, instead of steam, circulates throughout the system, and herein is one advantage due to the ease with which the temperature can be regulated.

Fig. 78. Stewart "B" Direct-Draft Furnace with Tubular Steel Radiator. Portable Form for Hard or Soft Coal
Courtesy of Fuller-Warren Company, Milwaukee, Wisconsin

Steam is generated by raising water to a temperature of 212 degrees Fahrenheit, and the radiators of a steam heating system are, consequently, always at about the same temperature. Regulation of the heat is secured by shutting off and turning on the steam at intervals, but with hot water the radiation is regulated by the tem-

perature of the water which is in circulation all the time. The latter is a distinct advantage in mild weather as it permits a smaller fire and a corresponding reduction in the consumption of fuel.

In the selection of the heating apparatus, the most important thing is to be sure that the heater, whether hot water or steam, is amply large to do the work. Our client has decided to heat his house by means of hot air, and we have advised him to put in a furnace which contains a good-sized air chamber in order that the rooms may be supplied with a large quantity of warm air rather than a smaller quantity of intensely hot air.

HOT-AIR HEATING

Furnace. For economy of fuel, we find recommended a furnace of the type known as *indirect draft.* In this type the heated gases are ordinarily obliged to pass downward to a radiating chamber at the base and thence upward again before escaping into the chimney, thus giving off a large proportion of their heat. Among other points to be considered in the selection of the furnace is the grate, which should be of a pattern that allows easy disposal of the ashes and clinkers without much disturbance of the fire. The construction of the fire pot is of great importance, and here the choice lies between a heavy cast-iron pot and a thin wrought-iron or steel pot with a lining of fire bricks. The cast-iron pot has the advantage of continuing to give off a considerable heat when new coal is put on, while the brick linings allow the furnace to cool more when the fire is dull. Other desirable features are a large combustion chamber, as the space above the fire is called, and ample heating surfaces so arranged that they will not become deadened by soot. We have selected our furnace not only with regard to all these points but also because of the smoothness of its castings and the evidently workmanlike construction of its joints and working parts.

In locating the furnace, it is necessary to see that the pipes are of about the same length, any differences being made in favor of pipes running north or west. The smoke pipe should be run as directly as possible and should never come nearer than 8 inches to the floor beams overhead. Care must be taken where the pipe enters the flue to make sure that the connections are tight, and that the pipe is not pushed in so far that it cuts off the area of the flue.

Cold-Air Box. The type of furnace chosen is made to set over a circular pit into which the cold-air box leads. An important consideration is the size of the cold-air box which should be of a capacity nearly equal to the combined capacity of the piping—about one-sixth less is the close rule, as the cold air will expand about that amount on being heated. Unless the supply from the cold-air box is ample, there will be danger that the long pipes will draw from the shorter pipes, or that the general flow will be weak and irregular. The opening of the cold-air box is usually placed on the north or west side, as the coldest winds generally come from those directions, but a better way is to carry the cold-air box completely across the cellar with a connection to the furnace at right angles, so that the latter may draw a supply without regard to the direction of the wind. If we build our cold-air box in this way, we shall avoid the very disagreeable experience suffered by all who have built their furnaces in the usual way—that of finding that when the wind is high from the side where the cold air is taken, the chances are that the air is driven through so rapidly that it does not get sufficiently heated, but comes in cold gusts from the registers. On the other hand, when the wind is strong from the side opposite to the single cold-air opening, the suction from the lee side of the house will often cause the air to flow down the registers and out of the cold-air box; in this case there is danger of the already heated air becoming hot enough by further heating to set the cold-air box on fire, if the box is of wood. To guard against such a possibility, it is best, if that can be done, to make all air ducts of galvanized iron, though these are, unfortunately, more expensive. In certain localities this metal construction is required by the building laws, and it is to be recommended in all cases.

Supervision. Beyond seeing that the apparatus, the piping, and the registers are ample in size and designed to heat the house properly, the superintendent should watch carefully to make certain that there is no danger from fire. All pipes which are run in concealed places should be double, or at least well protected by bright tin or asbestos covering, and by the use of wire for lathing over them. The furnace should have above it on the ceiling a circular shield of metal of ample size, or else plastering on wire laths. In running the pipes, sharp bends and sudden contraction or distortion

of the pipes must be avoided, and free entrance of pipes to the register boxes must be provided everywhere. The practice of topping pipes or running one pipe to supply two registers, is productive of continual annoyance, as it is almost certain that one register will get the greater part of the heat at the expense of the other. The registers should always be set in borders of slate or soapstone, or in the iron rims which are provided, and they should be free in action and tight when closed.

STEAM HEATING

Another efficient method of heating country houses is by direct steam radiation, which consists in circulating steam through radi-

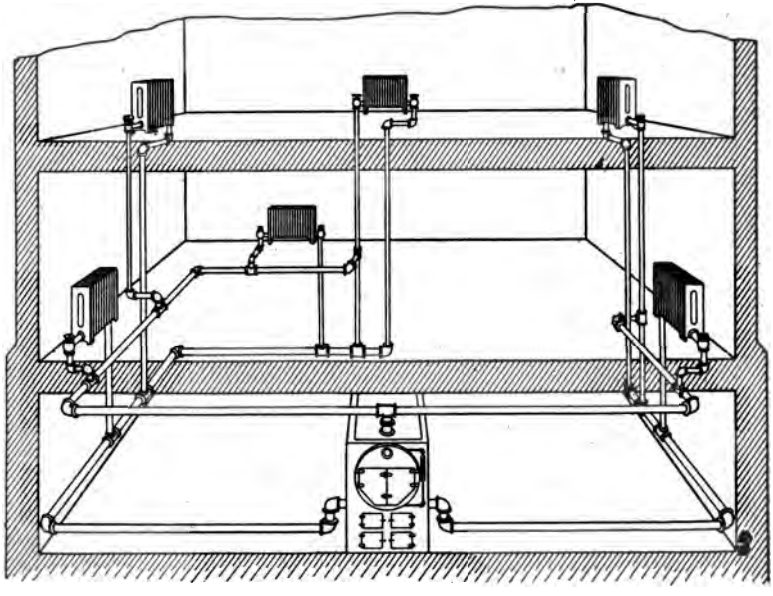


Fig. 79. Two-Pipe Steam Heating System

ators or coils placed directly in the rooms and halls. This may be done under high or low pressure, but the low-pressure gravity return system is generally used for house heating, from 2 to 10 pounds being rated as low pressure. Three systems of piping are used in this form of heating—called the two-pipe system, the one-pipe relief system, and the one-pipe circuit system.

Two-Pipe System. In the two-pipe system the main pipe is taken from the top of the boiler and carried by branches along the

cellar ceiling, pitching gradually down until all of the risers have been taken off, when it drops down and returns with a slight pitch to the boiler, below the water line, Fig. 79. This is called a "wet" or "sealed" return. Sometimes the return pipes are run overhead and this is called a "dry" return. The dry return is more productive of noise in the pipes than the wet return and is not so often used. In either case one set of pipes is run from the main supply pipe in the cellar to the different radiators, and another pipe carries the condensation from the radiators to the return pipe. This requires

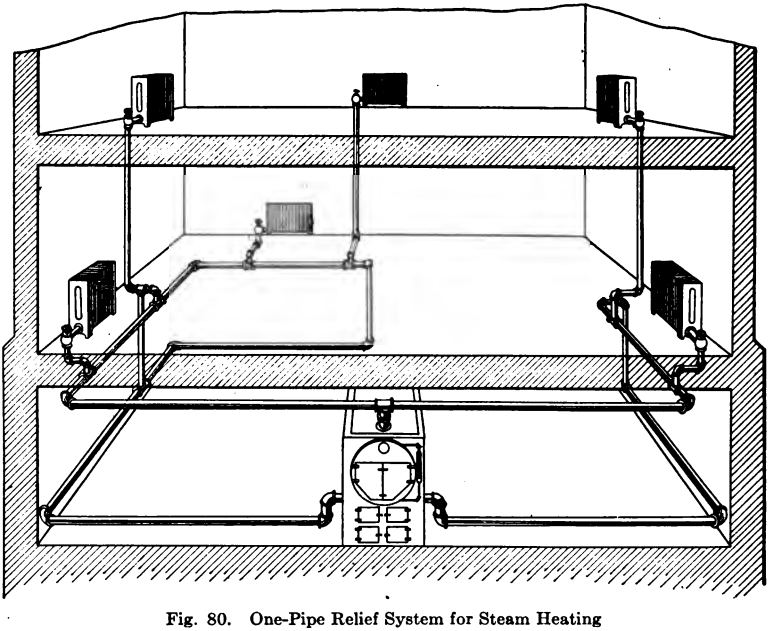


Fig. 80. One-Pipe Relief System for Steam Heating

two sets of pipes, valves, and connections, and is more expensive than the one-pipe systems which are generally used.

One-Pipe Relief System. In this system the arrangement of the cellar piping is the same as in the wet return previously described, but the supply to the radiators consists of but one pipe, taken off from the main supply in the cellar; the steam flows in and the condensation drains out through this single pipe to the main, and thence through frequent drip pipes, to the return pipe, near the cellar floor, Fig. 80. If the return pipe in the cellar is run overhead, as in

the dry return system, the drip pipes should be connected to the return main by a loop falling below the return, thus forming a trap and preventing the steam from flowing directly into the return.

One-Pipe Circuit System. In this system the main supply is carried to the ceiling of the cellar and there makes a complete circuit of the building at a downward pitch connecting again with the boiler below the water line, Fig. 81. From this circulation pipe, single risers are taken to the radiators, and the condensation flows back through the same pipes to the circulation pipe and is

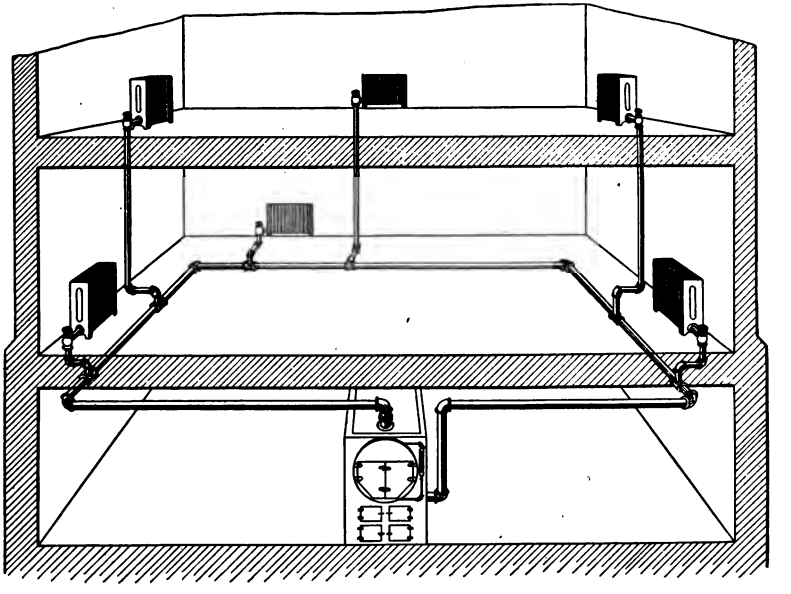


Fig. 81. One-Pipe Circuit System for Steam Heating

carried along with the steam and returned to the boiler. This circulation pipe should be of large size with a good pitch all the way.

In all single-pipe systems the piping must be larger than in the double-pipe systems, as the steam and the returning water are flowing through the pipes in opposite directions at the same time. This may be obviated by running a single riser to the top of the building where it branches out to supply the different radiators by separate pipes run back to the basement. In this case the steam and water flow in the same direction. For large work this method is often used.

Radiators. The form of steam radiator in general use is the cast-iron radiator, Fig. 82. It consists of a series of loops connected at the bottom; the steam, entering at one end, forces the air out of the valve placed about midway of the last section. The two end sections are of the same internal pattern as the others but are cast with legs.

Fig. 82. Typical Cast-Iron Radiator
Courtesy of American Radiator Company, Chicago

Pipe radiators, Fig. 83, are often used and, where design is not an object, the use of circulation coils of piping may be permitted.

Valves and Connections. Careful examination should be made of the valves and pipe connections to see that they are efficient and properly applied. Many styles of valves are available, and only well-known or well-tested patterns should be allowed. Of air valves for steam radiators the simplest form is the "pet-cock", a screw valve operated by hand, Fig. 84; but there are several forms of automatic valves on the market which allow the escape

Fig. 83. Wrought-Iron Pipe Radiator

of cold air from the pipes but are instantly closed when the steam reaches them. This is accomplished by the expansion of a metal part which closes the orifice.

Boilers. Many of the ordinary types of steam boilers are used for steam heating, and in addition to these there is a cast-iron sectional boiler which is used for dwelling houses to a great extent, Fig. 85. The main thing is to select some well-known type and to see that it is carefully set, with all attachments, which will usually be described in the contracts.

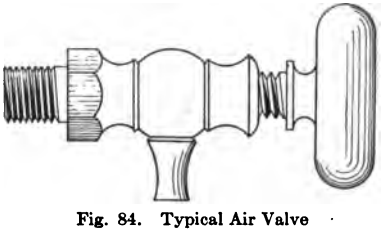


Fig. 84. Typical Air Valve

Details of Installation. This method of direct radiation lacks the advantage of the introduction of fresh air into the house, but, if care is taken to provide for that by other means we shall find the system desirable because it is economical and positive in its action. The important points to be watched are that heater pipes and radiators are amply large, and that the radiators are well placed and supplied by carefully graded pipes, tightly and neatly connected. Cellar pipes should be covered with some of the patented sectional pipe coverings, and radiators and all pipes which are exposed to view may be coated with bronze of a desired color. Where pipes pass through floors or partitions they should be protected by sleeves three-quarters of an inch larger than the pipes, and collars should be neatly placed around them at the floor and ceiling, or on each side of the partition.

Fig. 85. Ideal Sectional 36-Inch Steam Boiler
Courtesy of American Radiator Company, Chicago

Indirect Steam Heating. Other methods of heating are by indirect steam, indirect hot water, and a combination of hot air and

steam, and the same general principles will apply to these methods as to those which have been considered. The indirect application of steam or hot water is the system by which fresh air is brought to each register, after being heated by passing over a coil of steam or hot-water pipes, and while it is the most satisfactory of all means of heating, the expense of installation and maintenance is a bar to its employment for ordinary country or suburban house heating.

Vacuum Heating. A development of steam heating known as vacuum heating is a system suitable for large houses. It consists in installing in the basement of the house a vacuum pump operated automatically by town water pressure or by an electric motor. This pump, automatically controlled by the pressure in the pipes, removes the air from the pipes and radiators through automatic valves connected by a small pipe with the pump, allowing the steam to fill the system the instant it is turned on. This produces a prompt action throughout the whole system and thus effects a saving in fuel with less attention.

HOT-WATER HEATING

Another method of heating is by a similar application of direct hot-water radiation. This consists in circulating hot water through radiators placed in the rooms as in the case of direct steam heating. The hot water is conducted from the main heater in the cellar through the pipes and radiators, and the air is warmed by the direct radiation from these sources. The principle of this circulation is found in the difference in density and volume between hot and cold water. Water is at its greatest density at about 39 degrees Fahrenheit. When heated, its density decreases and its volume increases, so that as soon as the fire in the boiler is started the circulation begins; the water becomes lighter and flows up through the pipes, the radiators giving off its heat until, becoming colder and heavier, it flows back through the return pipes to the heater. This process is continuous as long as any heat is applied to the water in the boiler, the velocity of flow depending upon the difference in temperature between the supply and return, and the height of the radiators above the boiler.

Piping. The system of hot-water piping is that required for a free circulation of water from the heater to the radiators and

back to the heater again. The supply pipe is taken off at the top of the heater, and main and branches are run with an incline upward,

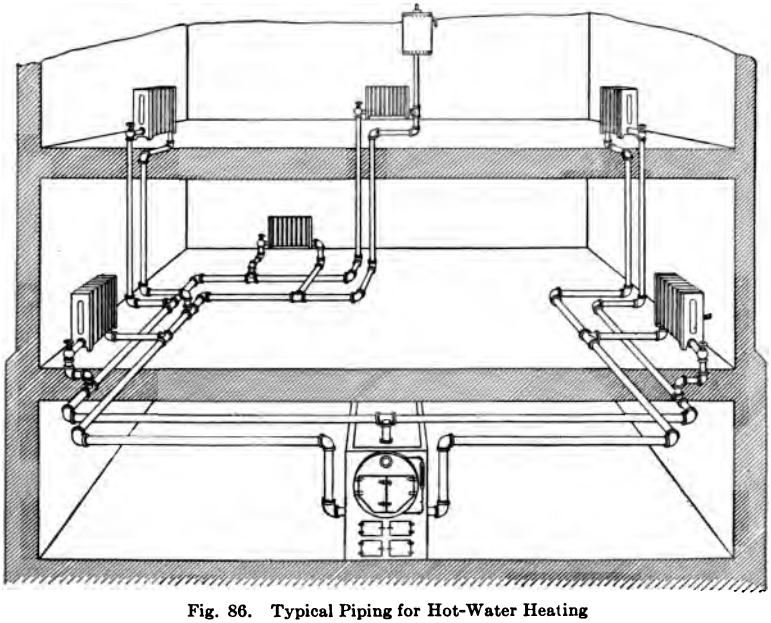


Fig. 86. Typical Piping for Hot-Water Heating

the return pipes being parallel to these and connected with the bottom of the heater. Risers are taken off the tops of the mains, and return pipes are connected with the return mains in the same manner, Fig. 86. As this system depends upon the force of gravity to keep up its circulation, an expansion tank, Fig. 87, must be provided, high enough above the highest radiator to insure free circulation, and the pipes ought to be run so that any radiator may be shut off without interfering with the general circulation. This tank should be supplied with a glass gage and an overflow to some convenient place, and an open vent pipe should be taken from the top. The connection from the heating system enters

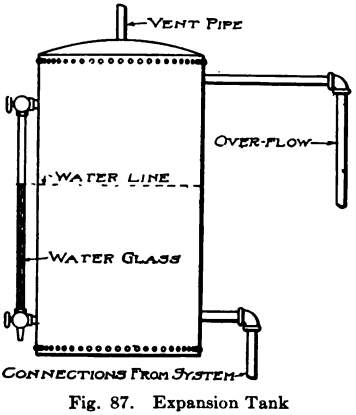


Fig. 87. Expansion Tank

at the bottom. An automatic connection should be made with the main water supply, and a connection should also be made at the heater to be used when the system is first filled, as by this means the air is driven upward and discharged through the vent on the tank.

The expansion tank should be large enough to contain a gallon of water for every forty square feet of radiation.

Radiators. Radiators for use with hot water differ from the ordinary steam radiators in having a passage at both bottom and top, Fig. 88. This is necessary in order to draw off the air which

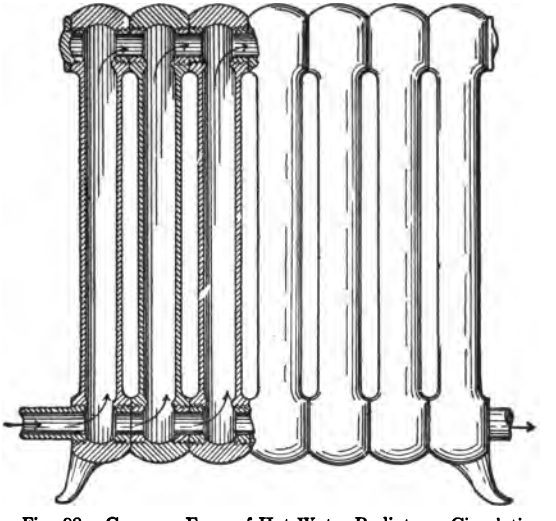


Fig. 88. Common Form of Hot-Water Radiator. Circulation Produced Wholly through Action of Gravity, Hot Water Rising to Top

gathers at the top of each loop. These radiators may be used for steam as well as hot water and connections may be made at either top or bottom. Sometimes the piping is so arranged that, instead of running pipes to each radiator from the heater, a single riser is carried up to the expansion tank from which pipes are run to supply the drops with which the radiators are connected, Fig. 89. In this case the radiators are supplied at the top and emptied at the bottom, and as the air in this system rises at once to the expansion tank and escapes through the vent, no air valves are required on the radiators.

Valves. Special valves are made for use with hot-water radiators, the main advantage of which is a device for quick closing, a half-turn being usually sufficient to open or close the valve. Connections with the radiators may be made at the top or bottom, the return pipe being always at the bottom. Only one valve is necessary to stop the flow of water through the radiator and this is put

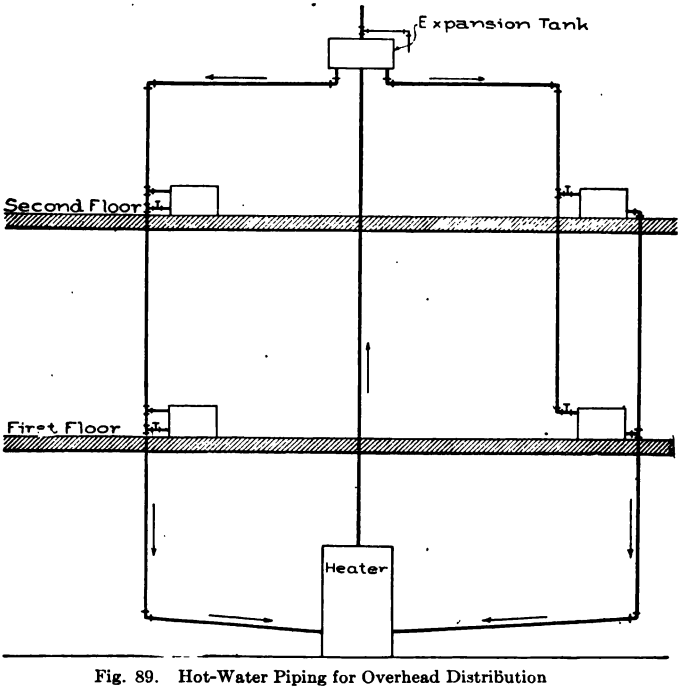


Fig. 89. Hot-Water Piping for Overhead Distribution

on the supply pipe, the return connection being made by a union elbow.

The ordinary petcock is generally used for an air valve, but there are several forms of automatic valves which are operated by a float that allows the air to escape when the water line is lowered but closes upon the flowing-in of the water.

Heaters. The heater differs from a steam boiler mainly in the omission of the space allowed for steam. The hot-water heater being filled with water in circulation instead of steam, it is essential that the heat should strike the surface in such a manner as to increase the natural circulation.

HEATING ACCESSORIES

Thermostats. Automatic devices for controlling the heat in a building may be applied to hot-air furnaces as well as to hot-water heaters and boilers. This device, called a thermostat, usually consists of a fixture applied to the wall of a room and connected electrically or mechanically with a motor in the basement which operates the drafts of the heater. When the air in the room reaches the desired temperature, connection is made by the expansion of some properly devised part which closes the direct draft and opens the check draft of the heater. When the temperature falls, the drafts are automatically reversed. Other types produce the same results by means of compressed air or by chemical energy, and all may be attached to a clock if action is desired at certain hours of the day or night.

Pipe Covering. Whether hot water or steam is installed, it is economy to cover the cellar pipes and the heater itself with an insulating material. For the piping, various types of covering can be obtained which are put on with bands and cement; for the boiler, a plastic covering is applied in a smooth coating which sets hard and strong. This insulation not only retains a large percentage of heat in the boiler and piping, but prevents the heating of the cellar, which is unnecessary and undesirable.

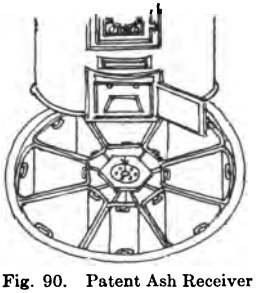


Fig. 90. Patent Ash Receiver

Ash Receivers. A useful but somewhat expensive arrangement for the care of furnace ashes is a set of underfloor ash receivers. This consists of a rotary carrier containing a number of ash cans of special radial shape, set so that one at a time they are carried under the ash box of the furnace and receive the ashes through an opening in the bottom of the box, Fig. 90. As the filled cans are revolved, they come under a removable plate in the top of the case at the level of the cellar bottom, and can then be lifted out and emptied. These receivers are arranged to contain two or three months' accumulation and so to do away with the frequent handling of the ashes.

A simple receiver consists of a single pail set beneath a cast-iron cover let into the concrete like a coal-hole cover. The ashes

are swept or shoveled into the can through a small lifting cover and, to remove them a larger cover is raised and the can lifted out. This same appliance is also adapted to receiving garbage; it may be set flush with the ground in the back yard, and the small cover arranged to be lifted by a foot lever.

INSIDE FINISH

Door Frames. After the furnace or heater is set and the plastering and concreting thoroughly dry, the inside finish of the house may be put up. The door frames, which should all have been

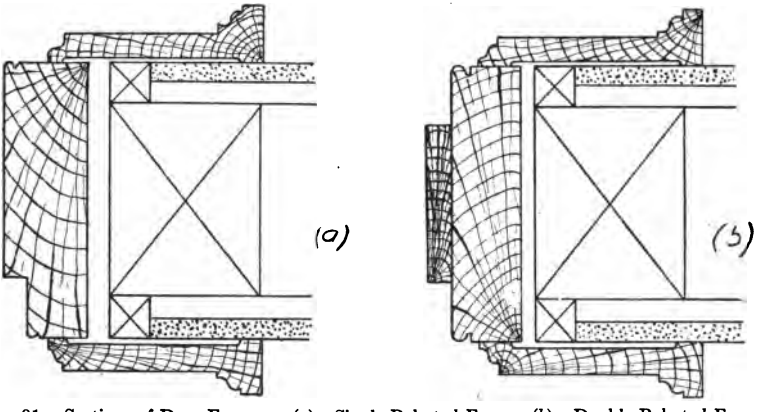


Fig. 91. Sections of Door Frames. (*a*)—Single Rebated Frame; (*b*)—Double Rebated Frame

ready, will first be placed, and great care must be taken to see that they are set square and plumb. If a single rebated frame is used, Fig. 91-*a*, the superintendent must see that it is set with the rebate on the proper side of the partition. Our specifications call for double rebated frames for all inside doors as in Fig. 91-*b*, and this not only does away with the necessity for such precaution but has the merit of allowing the doors to be finished at the same height and width on both sides of the partition and also makes it possible to have the door hung on either side.

Wall Board. It is sometimes desirable to omit the inside plastering of all or certain portions of a house and to substitute some one of the many wall boards or panel boards, Fig. 92, which have been put on the market for that purpose. These boards, built up in layers of fiber to thicknesses varying from about one-quarter inch to an

inch, may be obtained in sheets of different sizes up to 4 feet by 10 or 12 feet, and form a covering quickly applied and free from the dampness, dirt, and delay of applying plaster. They do not, however, make a surface so durable or continuous as plaster, or so fire-retarding, or impervious to sound, while if applied in rather narrow

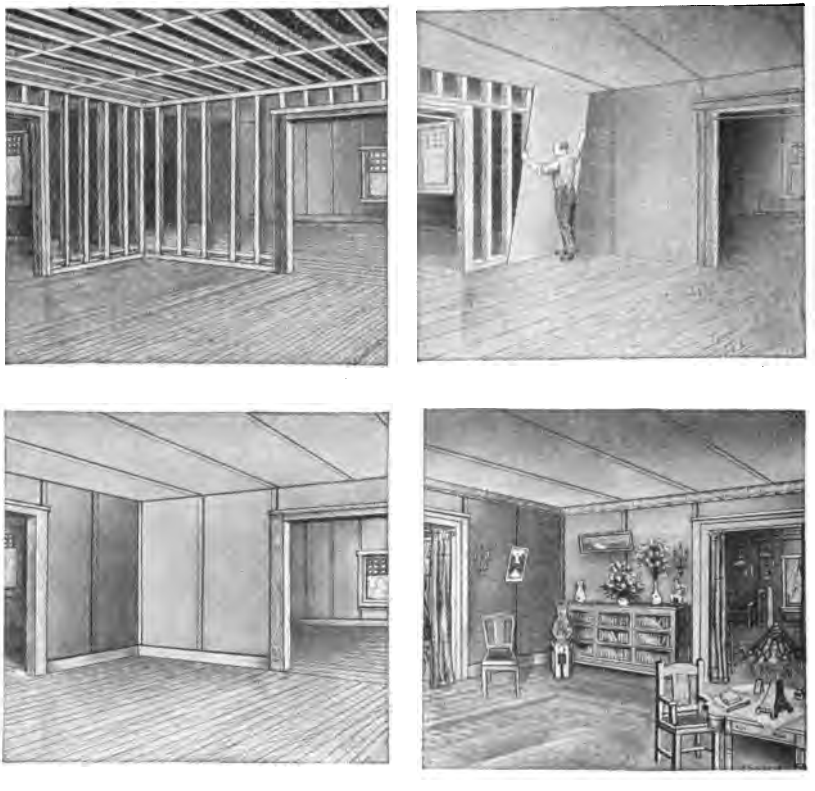


Fig. 92. Views Showing Mounting of Wall Board. Upper Left—Studding Ready for Ceilboard; Upper Right—Board Panels in Place; Lower Left—Panel Strips Mounted; Lower Right—Finished Room

Courtesy of Philip Carey Manufacturing Company, Cincinnati, Ohio

widths, with a good-sized strip covering the nailings—which is important—the final cost is about the same as plaster.

When wall board is to be used the studs should be set with reference to the divisions intended, and the directions of the manufacturers of the board, which accompany each order, should be carefully read and followed. Where the joints are to be covered, nails with a large flat head should be used; but if an extensive surface

for papering or other treatment is desired, the joints should be carefully made, secured preferably with nails of the "bunghead" type, which sink into the fabric for puttying.

Beam Ceilings. The application of beams on the ceiling follows almost as a necessity the use of wall board in place of plaster. The beams may be provided for in the framing and made a part of the real construction of the house; or they may be applied to the underside of the floor construction; or they may be of lighter design, used simply as divisions of the ceiling in a decorative way. In the latter case it will simplify the construction if nailing pieces, a little less in width than the breadth of the finished beams, are inserted flush with the plaster, Fig. 93. If the finished beams are very light these pieces may be above the plastering, in which case it is possible to change or omit the final beams if later circumstances make it desirable to do so.

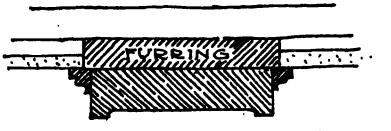


Fig. 93. Section Showing Nailing Pieces for Beam Ceilings

For light beams, employed to cover the joints in wall board applied to ceilings, there is carried in stock by many dealers in wood finish an adaptation of the combined cornice and picture molding which makes an inexpensive finish and will give a good effect if the moldings are of pleasing design. These stock moldings are also run with grooves on the top, making them available as plate rails when set down on the wall below the ceiling, Fig. 94.

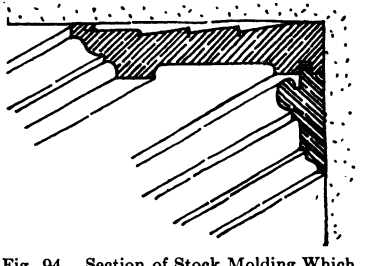


Fig. 94. Section of Stock Molding Which May Be Used for Plate Rail

Architraves. The next operation is to place the door and window architraves, called in some localities door and window "trim" although "casing" is perhaps the more common term. There are two principal methods of casing a door or window—the block casing, and the mitered casing, Fig. 95. The block casing is the simpler and less likely to be disfigured by shrinkage, as the joints are all straight across the casing, and since this will not shrink endways, the joints do not open. The mitered finish is neater in appearance but

can be used only with thoroughly kiln-dried wood, as any shrinkage will cause the joints to open. Architraves of either kind are usually hollowed out on the back as shown, to allow each edge to fit closely to the frame and the plaster, and to avoid danger of displacement

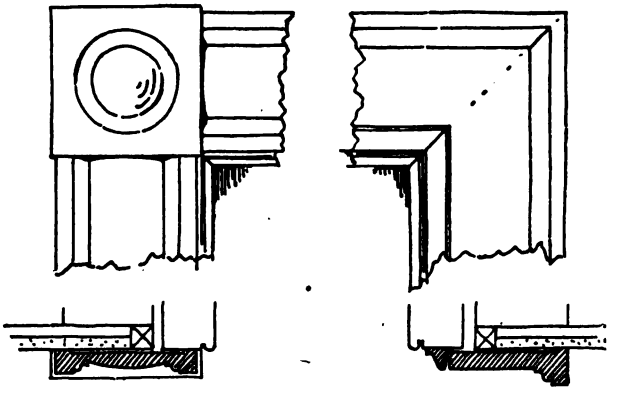


Fig. 95. Door Finish. A—Block Casing; B—Mitered Casing

by possible warping or twisting of the casing or ground. Plain blocks, called plinth blocks, Fig. 96, are often put at the bottom of the door casing to the height of the base. The superintendent should watch to see that all joints are carefully made, that margins are even on all sides, and that the moldings are securely nailed. The moldings must be scraped or sandpapered, or both, to remove all traces of the milling or planing, the effect of which is to leave marks upon the wood, imperfections that appear more noticeable after varnish has been applied. No casings should be spliced; long horizontal moldings, such as bases and wainscot moldings, will, however, have to be spliced, and care should be taken to see that this is neatly done.

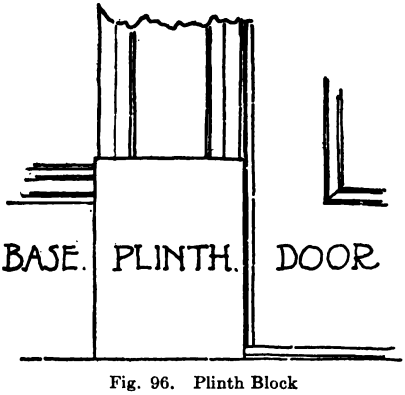


Fig. 96. Plinth Block

If the casing is to be painted, it is customary to nail the finish to the walls and frames with finish nails, well set for puttying. The

nails should be driven in the quirks of the moldings as much as possible. For hardwood finish all the members that can be should be glued together at the shop, and no more nails used than are absolutely necessary. Wainscoting, if paneled, should be put together at the shop in as long lengths as possible, and painted on the back before setting, and angles and corners should be rebated together, Fig. 97.

The projections of moldings, as well as chair rails, should be studied in connection with the architraves to be sure that the two will come together in a satisfactory manner. Where a dado is used, the line of the window stools will sometimes be made the top of the cap, and in this case especial care must be taken to see that the window frames finish at the same level. Where a chair rail only is employed, it is generally set about three feet above the floor. Bases and chair rails which run between doors and windows can generally be obtained without splicing. Picture moldings if set any distance below the ceiling will need especial attention to be sure that they are level and securely nailed.

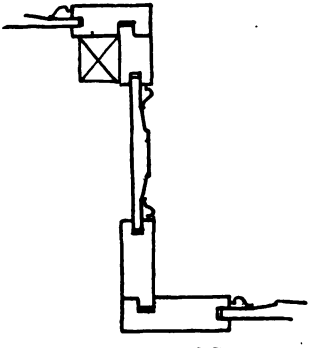


Fig. 97. Rebated Corner

Stairs. Close attention must be given the stairs to secure a satisfactory result. In the beginning the stringers must be examined to see if they correspond to the plans in the number of steps, and if ample headroom is provided where one flight of stairs comes over another. The plans will show the number but not the height of the risers, as the height can be determined only by dividing the whole distance from top to top of floors by the number of risers shown. This should have been laid out to give for ordinary stairs a rise of about $7\frac{1}{2}$ inches, and the sum of the tread and rise should make for an ordinary house staircase between 17 and $17\frac{1}{2}$ inches, so that with $7\frac{1}{2}$ inches for the rise, the tread would be $9\frac{1}{2}$ or 10 inches. Another rule is that the product of the rise and tread should be from 70 to 75 inches: that is, if the rise is 6 inches, the tread should be from $11\frac{2}{3}$ to $12\frac{1}{2}$ inches. For stairways where the space is limited winders may be inserted, Fig. 98, but where there is ample room, it is well to avoid them.

The question of headroom is an important matter and one that is not easily foreseen, so that often costly stairways, which are otherwise well conceived, are spoiled by lack of sufficient headroom. With floors of the thickness of those in ordinary dwellings, the well-room should extend over at least thirteen risers, and where one flight comes directly over another, 7½ feet in the clear, over the face of the riser, should be allowed.

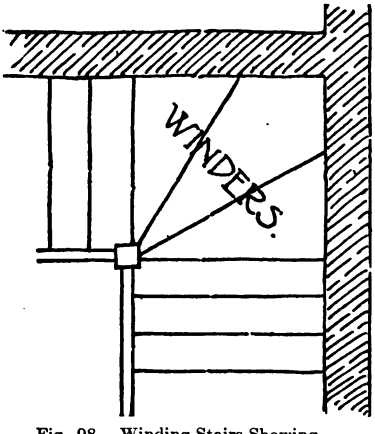


Fig. 98. Winding Stairs Showing Landing Details

In the construction of stairs methods vary somewhat. In New England it is customary to build the finished work of the stairs upon the rough stringer, piece by piece. The treads and risers are brought from the shop all fitted, and are nailed into place; the risers are first put on, grooved at the bottom to receive the tongue of the tread, and the tread grooved on the underside and fitted over a tongue in the riser, Fig. 99. A small molding is then put in the angle under the edge of the tread, and this finish is carried around the end of the step in "open-string" flights where the tread appears at the end, Fig. 100. The inside or wall edges of both tread and riser are grooved on the line of the base, the lower edge of which is scribed to the outline of the steps and cut away on the back to form a tongue, which, after the steps are all in place, is driven into the grooves, the stair nosing being cut away. This is necessary to prevent the appearance of a crack along the whole wall end of the stairs, which would otherwise invariably occur because of the shrinkage of the stairs and base; but unless carefully watched this operation is likely to be omitted, as the fitting and tonguing of the base is a difficult matter.

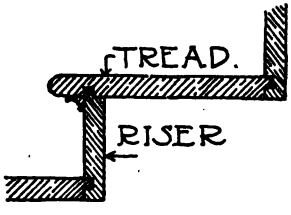


Fig. 99. Section of Stair Tread and Riser

In the English method of stair construction, the finished stairs are put together at the shop, brought bodily to the building, and

fitted to the rough stringers. In this method the wall ends of the steps are grooved into the base, or wall stringer, and wedged and glued. The outer stringer, if a close or curb string, Fig. 101, is tongued and fitted into the treads and risers. This method of housing is also sometimes used when the stairs are built at the building. One objection to the English method is found where the stairs are plastered underneath, for in that case there is no good chance to fit and wedge the finished steps to the rough work; but where the underside of the stairs is paneled there is ample opportunity to wedge the work solid, which is necessary to prevent a very disagreeable squeaking. In open-string stairs, before the end nosings are put on, the treads should be dovetailed at the end for the balusters, and when these are fitted in, the nosing will make them secure. This should be done in all good work, although the general practice is merely to nail the balusters at the bottom.

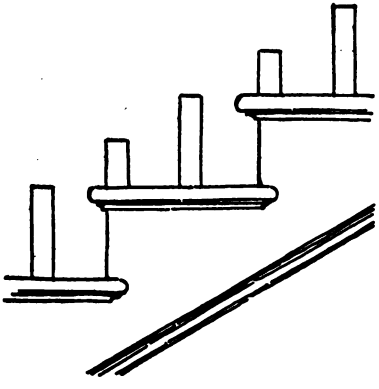


Fig. 100. "Open-String" Stairs

Against the sloping rail the balusters may be firmly nailed, but the rail must be secured to the posts by bolts, made for the purpose, which are let into the end of the rail, Fig. 102. Where the stair rail comes against the wall it is better to put a half-post than to allow the rail to run into a plate, as will be done unless the half-post is shown or specified.

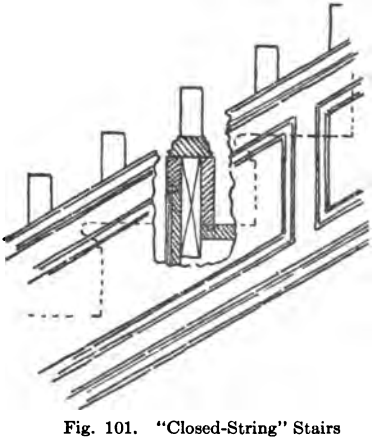


Fig. 101. "Closed-String" Stairs

Supervision. The erection of the stairs should be closely followed by the superintendent, as there is a great opportunity to slight their construction. If put together at the building, the rough stringers should be carefully verified to see that the treads are

level and the risers all equal. The cutting of the stringers is a matter of great nicety, and mistakes are often made which the workmen will sometimes try to remedy by tipping the stringer, backward if it is too long, or forward if too short, *A*, Fig. 103, or by reducing or adding to the top and bottom riser *B*. This detail should be watched for and never allowed, as a slight difference in the height or level of the steps is a source of danger. If the English method is used, especial care must be taken to see that the finished work is securely blocked and wedged.

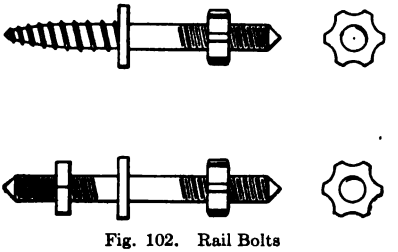


Fig. 102. Rail Bolts

Windows. As a part of the finishing of the inside of the house comes the adjustment of the sashes and doors. The sashes are held in place by stop beads, which are strips of wood usually one-half inch in thickness and of varying widths, according to the thickness of the sashes and of the walls, Fig. 104. These stop beads should always be secured by screws, as it will sometimes be necessary to remove them to adjust or replace the sashes. Special screws are sold for the purpose, which have a washer with a horizontal slot, that permits, by simply loosening the screws, the slight adjustment made necessary by the swelling or shrinking of the sashes. Before applying the stops the sashes must be carefully fitted and balanced, and as they will vary somewhat in weight, the matter of a perfect balance requires close attention. The superintendent should see that each sash is so balanced that there will be no great effort needed to raise or lower it, and no danger of its banging by reason of too much or too little weight.

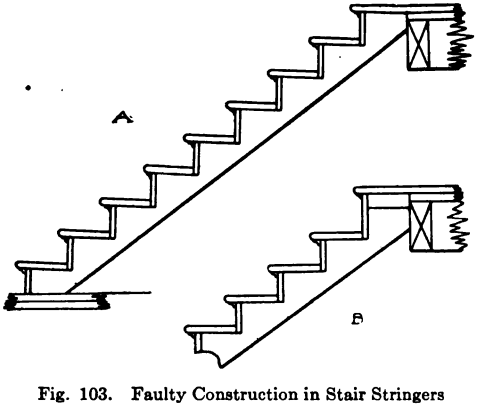


Fig. 103. Faulty Construction in Stair Stringers

Hardware. The superintendent must also closely examine the

hardware to make sure that it is as specified and is carefully put on. Sash fasts are often badly set, and each one must be tried to see that it works properly and easily. Pulleys should be carefully inspected to see that they are as specified. These will probably be already set in the window frames when they are received, and unless the contractor has paid especial attention to them they are very likely to be of an inferior order. The difference between a *plated bronzed* face and the *solid bronze metal* face called for by our specifications is often overlooked, and the bearings will be inferior if not carefully examined. A steel axle pulley may be used for ordinary work, but for better service a turned or milled axle is preferable.

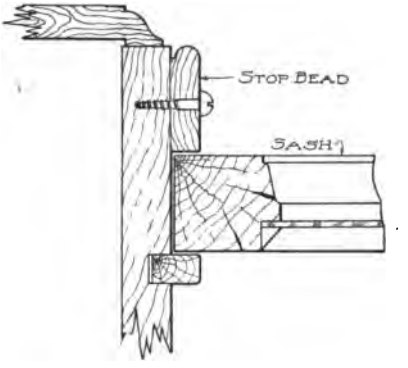


Fig. 104. Window Stop Bead

Cords, chains, and metallic ribbons are used for hanging the sashes, but for windows of ordinary sizes a good braided cord is perhaps to be preferred, this depending upon local custom. The size and particular brand of cord should be specified and care taken to see that this is furnished. The leading manufacturers have adopted a copyrighted device of a spot or name which appears at short intervals upon their cord and which, if noted, will prevent the substitution of any other.

For large sashes with no vertical bar, such as are shown in the main rooms of our house, sash lifts should be used. These are metal fixtures applied to the lower or side rims of the sashes to afford a hold for the fingers when raising the sash. When windows are as wide as those shown and have no vertical bar, the habit of starting to raise the sash by lifting on the middle rail will result in loosening the putty and springing up the rail, and for that reason lifts are necessary. They may be of the ordinary hook shape, or they may be a metal slot let into the lower sash, Fig. 105.

Mullioned Windows and Casements. The present tendency to group the windows of a house demands special hardware for the mullioned windows and also for casements. The design of the

mullions often requires that the divisions between the windows should be as small as possible. Where this prevents the use of the ordinary weights for sliding sashes, spring pulleys may be installed either in the side jambs, or overhead if the vertical divisions are very small.

Casement windows present a difficulty peculiar to themselves. The long casements which give access to outside balconies or verandas are not usually difficult to manage as they are, in effect, doors, and can usually be treated in a manner similar to the doors. The main difference is that the windows are often in pairs, and, whether double or single, the vertical stiles are generally made much smaller than for wooden doors; care must be taken, therefore, to select hardware small enough to fit the narrow stiles.

Fig. 105. Sash Lifts
Courtesy of P. & F. Corbin Company, New Britain, Connecticut

Short casement windows, used in the place of the ordinary sliding sashes, introduce a problem which requires special treatment. The owner will usually have definite ideas as to whether the casements should open out or in, and in either case complications at once arise which demand special consideration and recommendation by the architect. If the sashes are to open out, the ordinary outside blinds and fittings cannot be used. Then, too, the screens must be put inside of the sashes, and, if the fastenings are of the usual kind this means that the screens must be hinged and open in, to the detriment of draperies and curtains. If, on the other hand, the sashes are to open in, the sashes themselves will interfere with the draperies and will be, besides, harder to keep tight than sashes opening outward; the screens, moreover, if placed outside the sash, will interfere with operating the blinds or shutters in the usual way.

To overcome these difficulties, special adjusters have been devised which permit the opening and closing of either outside blinds or sashes without opening the intervening screens or sashes. The least conspicuous of these consists of a pivoted arm to be set in the space between the sash and the screen, Fig. 106, the pivot extending down through the sill and connecting with a rod or arm

brought through the sill to the inside, where a sideways movement opens or closes the sash or blind. Another pattern is set on the top of the sill and works entirely in sight, the lower rail of the screen being made wide enough so that it can be cut out to fit over the pivot, Fig. 107.

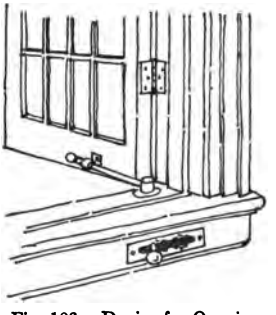


Fig. 106. Device for Opening Casement Windows

Doors. The last of the interior fittings to be installed are usually the doors. They are of two classes—stock doors and doors made to order.

Stock Doors. These are made in certain regular sizes, are generally of pine, whitewood, or cypress, and may be obtained at all times from the dealers. They are of three grades, A, B, and C, the first of which may be used for the cheaper portions of good houses; but, because they have been stored for a greater or less time, stock doors are generally not thoroughly dry and will shrink and twist when subjected to furnace heat. Stock doors of the second and third qualities are very inferior articles and should be used only for the poorest kind of work.

Doors of excellent quality and design are now made with built-up cores, and specially sawed veneers producing large plain panels or a wholly plain surface, Fig. 108. These doors are held "ready to ship" in a great variety of styles in birch or oak, and are manufactured to order in any other wood. They also come with a full length mirror on one side such as is often used in bedrooms or dressing-rooms. If these are installed, it is well to place them where they will be in least danger of breakage when not in use, and also where there will be room to stand far enough away from the glass to allow a good view.

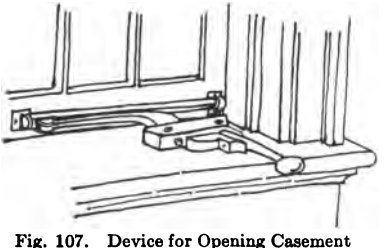


Fig. 107. Device for Opening Casement Windows

Custom-Made Doors. The doors of the principal rooms should be built to order. If of pine or whitewood they may be made solid but must be of kiln-dried stock and kept perfectly dry. The tenons should be made, as specified, with haunches, Fig. 109, and the panels

put in without bradding or gluing, so that they may swell and shrink without cracking. Hardwood doors are veneered upon a core of well-seasoned pine and should be examined upon delivery to see that this is done and that the veneers are of the proper thickness. The veneers should be $\frac{1}{4}$ inch on the face and at least $\frac{3}{4}$ inch on the edges, to allow for fitting. If the panels are of great width they also should be veneered, with the grain of the core running at right angles to the grain of the veneer. Doors which are to show hardwood on one side and a painted finish on the other should be veneered on both sides to prevent warping, which may occur if one side only is veneered. In the design and selection of doors care must be taken that the panels are so divided that the lock in its normal position will not cut off the tenon of the rail but will come opposite a panel, Fig. 110. The rails of a door are always tenoned into the outside stiles, and if there is a middle stile, that is tenoned into the rails, Fig. 111, so that the tenon at *A* is an important factor in the strength of the door and should not be weakened or destroyed by being cut for the lock.

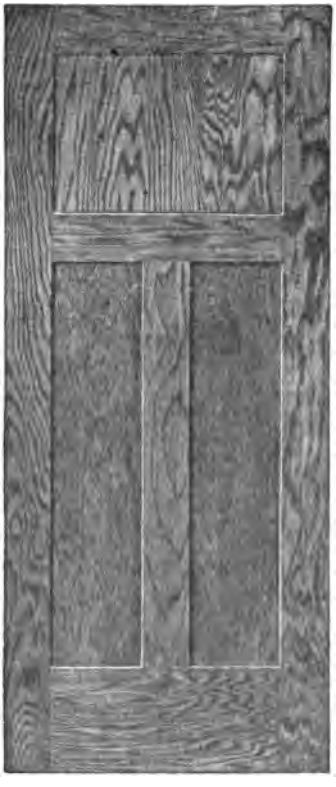


Fig. 108 Stock Oak Door
Courtesy of Morgan Sash & Door Company, Chicago

Hardware for Doors. The hanging and fitting of the doors is a matter of great nicety and should be intrusted only to careful workmen. The hardware for an ordinary door will consist of the hinges, or butts, the lock, knobs, and escutcheon plates. Double doors will need in addition bolts for the standing part. Sliding doors will be hung on a hanger, and the fittings must necessarily be flush to allow the door to slide into the wall. The specification of hardware for doors is often made a matter of an allowance—either a certain price is fixed per door, or a sum is named to cover all the

hardware of the doors, the selection being left to the architect or owner. The latter method has been adopted for our house and the architect's knowledge becomes necessary in guiding the owner to a proper choice at the dealer's rather than in inspecting the hardware at the building.

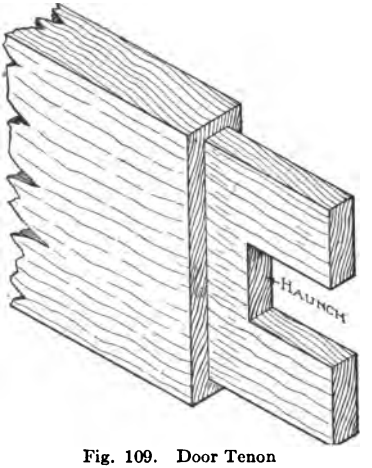


Fig. 109. Door Tenon

Hinges. In the selection of hinges the choice of material will be principally between solid bronze or brass, and plated, japanned, or lacquered iron or steel. If of solid metal the best quality only should be used with steel washers and bearings, as the soft metal will otherwise wear out from the swinging of the door. Modern door hinges are invariably made in parts, to allow the door to be removed without unscrewing the hinge, and this is accomplished by two methods, the *loose-joint butt* and the *loose-pin butt*. The former consists of a hinge made in two parts, Fig. 112, the section containing the pin being screwed to the door frame and the other section screwed to the door; this permits the door with its half of the hinge to be

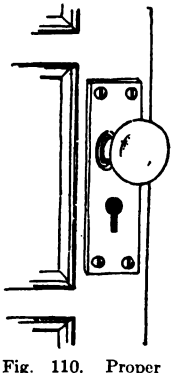


Fig. 110. Proper Location for Latch and Lock

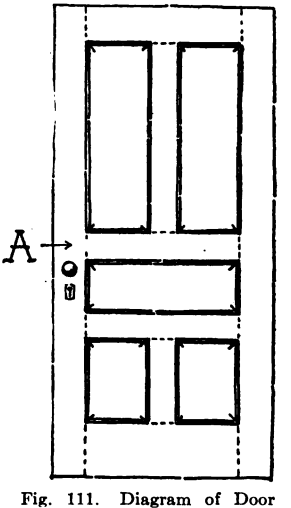


Fig. 111. Diagram of Door Showing Location of Lock to Avoid Weakening Door Tenon

lifted off if desired. With the loose-pin butt, Fig. 113, the door is removed by drawing out the pin and slipping the hinges apart. Loose-pin butts are coming into more general use than formerly and possess some advantages. In the first place, the bearing surfaces are multiplied, and since the pin is separate from the leaves, it can be made of harder metal. Again, as either leaf can be fastened to the door or jamb, the same hinge can be used for a right-hand or a left-hand door, and the fact that the pin can be withdrawn makes it possible to open the door even when locked. This may sometimes be a disadvantage, however, and that fact should be borne in mind

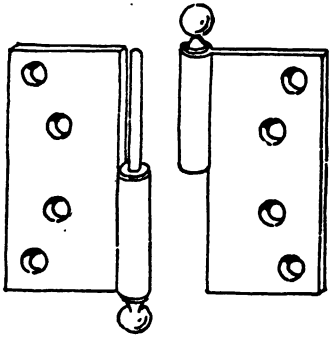


Fig. 112. Loose-Joint Butt

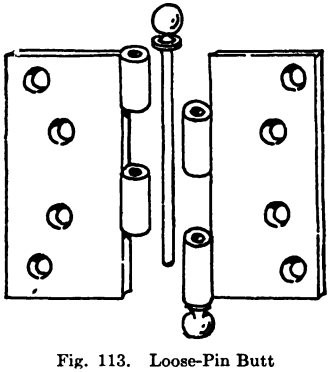


Fig. 113. Loose-Pin Butt

in planning doors which open out of a room that must be made secure.

Locks. The variety of door locks is so great that mention can be made of only some of the distinguishing features. According to their construction, locks are generally either *tumbler locks* or *cylinder locks*, and according to their position on the door, they are either *rim locks* or *mortise locks*. Tumbler locks are the ordinary kind of lock operated by a long key, Fig. 114, and depend upon tumblers or levers which are raised by the key to an exact position before the bolt can be thrown. Cylinder locks consist of two cylinders, a small one rotating inside of a larger one and turning only when a key of the proper shape and size is inserted, Fig. 115. Cylinder locks are not so easy to pick as tumbler locks, and there is less danger of an accidental exchange of keys, so that they are recommended for outside doors or wherever special security is desired.

Rim and mortise locks differ only in the form of the case, rim locks being made to screw on the face of the door, Fig. 116, and mortise locks being let into the edge of the door, Figs. 114 and 115, the inside construction of both being the same. For ordinary house use, a three-lever lock with brass or bronze face is good enough, but a cylinder lock may be used to advantage for the outside doors. The latch and lock will generally be found in combination and may be used with a long plate covering both knob and keyhole, or with a separate treatment of the keyhole by means of an escutcheon, Fig. 117.

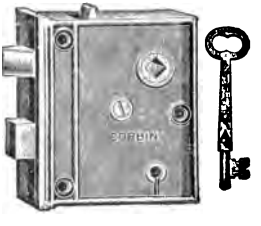


Fig. 114. Typical Tumbler Lock
Courtesy of P. & F. Corbin Company, New Britain, Connecticut

Knobs. Whatever treatment of escutcheon plate is adopted, the knobs and spindle will be the same and may be selected from a variety of materials and shapes. The cheapest knobs are of composition and are commonly called mineral, jet, or porcelain knobs. Wood finished in natural color is used to some extent, and glass as well. All of these are sold with bronze shanks and escutcheons. A better class of knob, and perhaps the most satisfactory of any, is one of brass or bronze, either wrought or cast and in a wide variety of shapes and finish.

Fig. 115. Typical Cylinder Lock

Bolts. Of greater protection than locks on a door are bolts, which, being operated from one side only, are secure against picking. The simplest and least noticeable of these are the mortise bolts, which set in a hole bored in the edge of the door and are operated by a knob or key on the face. Chain bolts are a protection in localities infested by tramps or other intruders. These bolts consist of a strong chain which is secured to the frame and hooks into a slotted plate on the door. The door can be opened only to the length of the chain, and not until it is closed can the chain be again dislodged, Fig. 118.

Miscellaneous. The many small fittings, such as coat hooks, drawer handles, cupboard latches, and the like, should be selected for strength and utility rather than for effect, and are the most

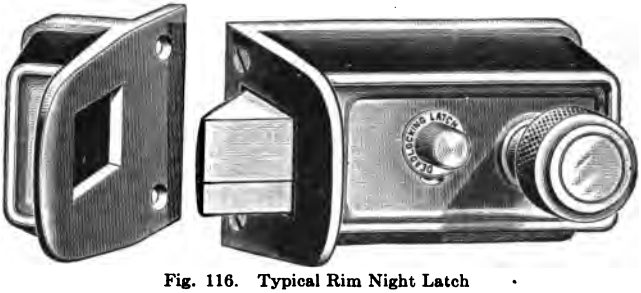


Fig. 116. Typical Rim Night Latch
Courtesy of Sargent & Company, New Haven, Connecticut

satisfactory in plain bronze or brass. Those of good manufacture and material can be obtained at moderate prices.

Supervision. The inspection of hardware is an important matter, whether it is furnished by the owner or the builder, as any changes made after fixtures are once applied are certain to produce defects of some kind. What purports to be bronze may be some baser metal, skilfully bronzed or lacquered on the face. This may be detected by scraping the back with a knife or file. The faces of locks or bolts may be plated instead of being solid. Knobs may be poorly fastened to the shank, and may lack the washers necessary to prevent rattling; and hinges may be furnished with no washers so that they will soon wear and creak.

Fig. 117. Plate and Escutcheon

In the application of the hardware, also, it is necessary to keep a sharp watch. Even in so simple a matter as putting on door hinges there is a right and a wrong way, for if the butts are not directly over each other the door when opened will swing either backward or forward. Mortises must be accurately cut so that the locks will be neither loose nor so tight that they cannot be removed if required. Roses or escutcheon plates must be put exactly opposite each other or else the spindle will bind in the lock. Knobs must be

carefully adjusted by means of washers so that they will not slip back and forth. Striking plates for latches, Fig. 119, must be carefully centered and adjusted. While all hardware is usually packed with screws finished to match, the screws are often too small and

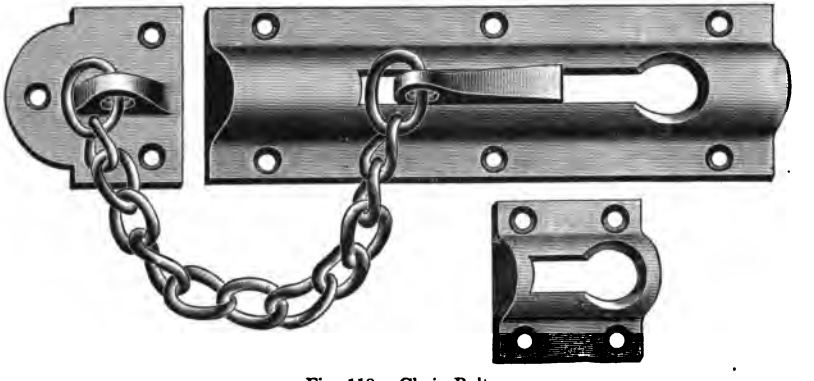


Fig. 118. Chain Bolt
Courtesy of P. & F. Corbin Company, New Britain, Connecticut

their efficiency destroyed by being driven in with a hammer by careless workmen. This should never be allowed, but every screw should be set with a screw driver. Good-sized screws are especially important in door hinges, and the hinges themselves must be big enough to allow the door to swing entirely back. The greatest vigilance is necessary to make sure that the hardware is free from defects of selection or application, and nothing will reflect more credit upon the superintendent than a good job in this part of the work.

Fig. 119. Striker

Screens. It is well at this time, if the matter has not already come up, to see if the construction of the fly screens is far enough advanced so that they can be installed as soon as the outside painting is finished. The screens may have a wood or a metal frame. In either case they should be made so that the wire can be replaced if necessary. Copper wire, or an alloy of copper which will not rust, makes the most durable screen, but galvanized or "pearl" wire is good enough for ordinary use. This may be painted black if the look of the glistening wire is objectionable, but copper or bronze wire soon tarnishes and darkens in color.

Screens for the main part of the house are usually made to cover one-half of the window only, but the guides or runners should be full length so that the screen may be used at either the top or bottom half of the window. For the service portion of the house it is well to apply an outside screen of the full size of the opening, so that the windows may be opened top or bottom without stopping to see if the screen is in place. Screen-doors should be provided for all outside doors and French windows, and attention must be given to them in time to make certain that they correspond in the main divisions, to the solid door or window at which they are to be placed. It will also be necessary to designate the style and finish of the door hardware, so that the screen hardware may correspond.

Floors. When the inside finish has been put up, the rough under floors should be gone over, all holes and broken boards repaired, and the floors cleaned off, ready to receive the finished floors. The laying of these, if they are of hardwood, is generally let to a special floor-layer, but sometimes it is done by the carpenter. For the carpeted rooms a good quality of square-edged spruce flooring not over 4 inches wide will be used. It is best to have the boards laid in one length, but if this cannot be done, the range of joints should be broken as often as possible. If the boards are of the same width they can be broken every course, but when the boards are of unequal width there will be a straight joint through three or four boards. The nails of a square-edged floor are driven through the face of the board and sunk with a nail set, to be puttied or not, according to whether the floor is to be finished or left plain. A line should be drawn where nails are to be driven, over the center of the joist below.

Floor Paper. Between the upper and under floors it is well to lay a deadening layer of paper. This may be asbestos felt, which is valuable on account of its fire-resisting qualities, or a common floor paper. It should be put down in two thicknesses.

Matching. Where finished hardwood floors are used, it is necessary to have the floor boards matched so that the nails may be concealed. In blind nailing, as this is called, the board is nailed only on one edge, and the matching is depended upon to hold down the other edge. For this reason the floor should be laid of narrow strips each with a tongue and groove, the grooved edge being forced

over the tongue of the preceding strip and the tongue in turn nailed diagonally, Fig. 120. The boards for under floors, where a handsome upper floor is desired, should be narrow, not over 4 inches wide, for each board in shrinking will compress as many strips of the upper floor as may be upon it, leaving a wide crack over the crack in the under floor. This defect may be overcome by laying the under floor diagonally or at right angles to the upper floor.

Stock. Of flooring stock in general, quartered oak makes the best floor for appearance and wearing quality, but birch and maple are used to a great extent, and rift hard pine makes a good floor for ordinary use. Quartered oak is sawed from the trees as nearly as possible on radial lines, Fig. 121, and shows an even, straight grain with irregular streaks, upon a ground of fine parallel lines. In rift hard pine the parallel grain is more pronounced and of a coarse growth. All flooring must be kiln-dried and laid hot from the kiln, or as soon as possible after delivery. To obtain a perfectly even surface the floor must be "traversed", that is, planed across the grain.

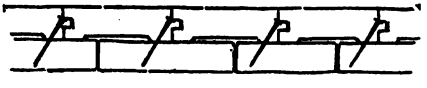


Fig. 120. Blind Nailing for Matched Flooring

A thin floor which is only $\frac{5}{16}$ inch thick is used to good advantage over an under floor which is in good condition. It is skilfully handled by a professional floor-layer, and is often laid to a more or less elaborate pattern. Being too thin to match, these floors are nailed through, and the nail holes so cleverly puttied as to be almost invisible.

While the floors and finish are being installed it is a good plan to have artificial heat in the building, which should be maintained until occupancy. This is especially necessary in the case of parquetry floors.

Composition and Linoleum. For the service portion of the house a floor may be laid of one of the many composition or monolithic floorings on the market. These are made from various formulas, having a base of cement, asphalt, or other plastic medium, and a wearing of cork, sand, or various substances imbedded or applied. When this kind of floor is used, it is customary to carry the floor, by means of a sanitary cove, up the side wall to form the base- or mop-

board. Heavy linoleum cemented to the wood, concrete, or other surface of the floor, makes an excellent finish which is easily kept clean and in sanitary condition.

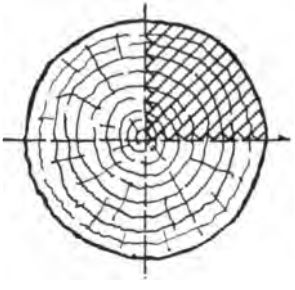


Fig. 121. Typical Log Section Showing Method of Quarter-Sawing

Final Details of Finishing. A number of different points connected with the finishing arise as the house nears completion, and the superintendent will do well to inspect the work constantly to see that every detail is being carried out as it should be. Thresholds should be carefully fitted, and cornices, chair rails, and picture moldings must run level and true. Sashes must be tried to be sure that they are accurately balanced and hung. Every sash fast, lock, and knob must be examined, and all drawers, slides, and other movable fixtures tested and left in good working order.

PAINTING

EXTERIOR PAINTING AND STAINING

Priming Coat. The outside finish of the house should receive as soon as put up the first or priming coat of paint. This is usually done more or less by piecemeal as the different parts of the house are completed, and requires the superintendent's attention mainly to see that the materials are pure and that the surfaces are well covered. This first coat should contain a large proportion of white lead, which adheres to the new wood far better than any other substance and retains the second coat well. Pure linseed oil should be used, but unless care is taken this is likely to be adulterated with fish oil, which dries slowly and never hardens like pure oil. The only way to detect the presence of fish oil is by its smell, and even this is sometimes uncertain. Linseed oil is also adulterated with oils of resin and pine, and these are difficult to discover except by long experience.

Before priming the painted finish, all knots, sap, and strong discolorations must be "killed" with a strong coat of shellac to prevent the staining which would otherwise occur. The painter must be required to examine the finish and report any defects, which must be remedied by the carpenter, and all finish should be gone

over with sandpaper before each coat. As regards the color of the priming coat, white or almost any very light tint will do. It is often well to include in the contract just two coats—the priming coat and the finishing coat—as the work will then be better done with less opportunity to cover up poor work and less liability to blistering than if three or four coats are applied at once; a third coat may be put on after two or three seasons to better advantage. An exception should be made with regard to sashes, which should have three or four coats immediately.

Puttying. After the application of the priming coat, all the nail holes and cracks must be stopped with putty, the nails having been previously "set" by the carpenter when the finish was put up.

Method of Applying Final Coat. The final painting of the exterior will naturally begin with the roof and be carried downward so that portions already done will not be spattered by subsequent operations. If the roof shingles are to be painted or stained they should have been dipped in the paint or stain, for a distance of at least two-thirds from the butt, before being laid. This is a tedious process but is well worth the extra trouble and expense. Another method is to paint each course of shingles as it is laid, but this is fully as objectionable a process as dipping. One or the other of these methods should be employed, however, if a painted roof is required, for the painting of a shingled roof after laying is fatal to the wearing qualities of the shingles. The reason is that the wet paint runs to the butt of the shingles and, trickling over the lower edge, forms a small dam or barrier on the shingle next below. Any water falling on the roof is held back by this dam under the butt of each shingle until it evaporates, meanwhile rotting the shingle upon which it lies and the butt above. This is especially damaging on a roof of low pitch.

Whichever of these methods has been used, however, the coloring of the roof shingles will have become hard by the time the walls are painted so that there will be no staining of the work below.

While it is essential that the first coat should be of lead and oil, for the subsequent finish this is not so important. Some of the patent mixed or chemical paints are convenient and will last well, especially away from the seacoast. Paint should be applied by long strokes parallel to the grain of the wood, and no portion of work

should be started in the morning which cannot be finished or carried to some definite stopping-place before night, as work done at different times can never be neatly joined. The back of lattice work should be painted and also all conductors, and the metal finish and roofs. Canvas roofs are best treated by being dampened and given a good coat of oil with yellow ocher, then two or three coats of lead and oil paint.

The use of turpentine is to be avoided in exterior painting, for turpentine does not resist the action of water and so will not preserve work exposed to the weather. As oil possesses a natural tendency to discolor white paint, it is customary to mix turpentine with the oil when an absolute white is desired, but in dark colors this is not necessary and boiled oil only should be used, unless a dryer is needed.

Choice of Colors. Concerning the choice of a color for the exterior of the building, a few general suggestions may be properly made here. In the first place, it is of prime importance that the house should be suited in its exterior colors to the surroundings.

If the house is to be surrounded by plenty of growth, such as trees and shrubs, so that the tints of vegetation will predominate, the tendency may well be toward shades of green, yellow, or brown, which will harmonize with the changing effects of the growth. On the other hand, if the situation is one where rocks and ledges will necessarily lend a grayish tone to the surroundings, the house may be suitably painted in shades of gray.

For a colonial design, such as we have adopted, the old-fashioned idea of painting the trimmings white with the body of yellow ocher or gray, may be properly considered. Of these, the gray body will prove the more lasting as the yellow ocher often becomes mildewed when exposed to continued dampness. In general, light colors last better than dark colors and do not "draw" the joints of the finish.

Use of Stains. For shingled houses, stains of various colors and ingredients are often used. These are not so durable as paint, but they have the merit of preserving the texture of the shingles, which is completely lost by the application of paint. Creosote stains, pine-tar stains, and oil stains may be obtained. The creosote stain acts as a preservative for the wood, especially if the shingles

are dipped before being laid. In the lasting qualities of these stains there is little choice; creosote and tar both disappear in time through the action of sun and rain, while the tendency of oil stain is to blacken or mildew.

Weathered Exteriors. In some situations a preference may be had for an unpainted exterior, the desired effect being obtained by the action of the elements. In this case, shingles should be used for the covering, as clapboards or siding are likely to split if not protected with paint. In any case, the exterior finish and moldings should be painted or they will warp and twist out of place.

INTERIOR PAINTING AND STAINING

Painting. While the same principles apply to the inside painting as to the outside, more pains must be taken in the work. Puttying must be done with the most particular care, and great skill in the application of the finish is needed. If the woodwork is to be painted, all knots and pitch must be thoroughly protected by shellac, even to the extent of shellacking the whole finish if it is necessary. For inside painting zinc is largely used instead of lead and is often preferred, as it has no tendency to turn yellow, as lead will sometimes do, in rooms which are not well lighted. Tastes vary as to the kind of surface for the painted wood. If a dull finish is preferred, it may be obtained by mixing the last coat of paint with clear spirits of turpentine instead of oil. Oil gives a somewhat glossy finish, and varnish mixed with the last coat gives a high gloss. The so-called enamel finish is very popular, and is obtained by the application of five or six coats of paint, each coat rubbed down with pumice and oil, the last coat being of a prepared enamel.

Staining. Staining in various tints is a popular way of finishing many interiors. This is done sometimes to change the natural color of hard woods, like oak, but more often to give a desired tone to softer woods such as whitewood or cypress.

Stains are, in general, of three kinds—water stains, oil stains, and spirit stains. The richest color effects are produced with water stains, for the reason that their work is performed by absorption and there is thus less tendency to obscure the grain of the wood. Oil stains are superior to water stains in preserving the wood and, because they do not freeze, their use in cold weather is an advantage,

but the result is a loss in clearness of grain and color effects. For renewal of old work, oil stains should be used as the previous finishing will prevent proper absorption of the water stain. Spirit stains tend to strike into the wood by evaporation, requiring about twice as much to cover the same area as water or oil stains, and they are not extensively used.

Natural Finish. When a natural finish is desired, the treatment will vary from the simple application of a coat or two of oil, which makes the cheapest and poorest finish, to five or six coats of shellac, rubbed down, which gives the most costly and best of all finishes. The treatment depends upon the wood and on the finish desired. We find that our painting specification has been very carefully drawn. The hardwood finish, after cleaning, is to have first a coat of oil or paste filler; this is to be cleaned off and four coats of shellac applied, each coat, except the last, to be rubbed down when dry with fine sandpaper, and the last to be rubbed to an eggshell gloss with pumice stone in oil. The hard-pine finish of the service portions of the house will have a good coat of oil to bring out the grain of the wood. This will be smoothed by sandpapering, and then given a coat of spar varnish, rubbed down, and a final coat of the same varnish, flowed on and left shining.

Processes of Finishing. *Preparation of Surface.* The first requisite for good work is that the surface of the wood shall be smooth and clean. This can best be secured by a careful sandpapering of all finish until it is perfectly smooth, when all traces of dust should be removed. If stain is to be used it may be then applied and, after drying, the wood lightly sandpapered to bring out the high lights and smooth the grain which will be raised somewhat by the application of the stain. A second coat of very dilute stain lightly applied with a cloth will often improve the grain. This may be followed by a thin coat of shellac to protect the solid parts of the wood from absorbing too much of the filler, thus heightening the contrasts and preventing the muddy appearance sometimes seen.

Filling and Finishing. The wood is now ready to receive the filler which should be used on open-grained woods such as oak, ash, chestnut, mahogany, etc. It may be either a paste filler or an oil filler, preference generally being given the former. This is applied in a thick coat, the surplus wiped off with a cloth, and the

whole sandpapered lightly. After filling, another coat of shellac may be put on and sandpapered, and this may be followed by two or three coats of varnish or shellac, according to the finish desired.

Shellac and Varnish. The choice of shellac or varnish for finish depends upon the use, condition, and situation of the work.

In damp situations, or where the finish will be subjected to the action of water to any extent, it is better to use varnish, as the effect of water is to turn shellac white. Varnish when perfectly dry is not affected by ordinary applications of water. For this reason, if there is any suspicion that the wood is not thoroughly seasoned, it is safer to use varnish in direct contact with the wood as the final seasoning of some of the more "sappy" woods, such as cypress or hard pine, will sometimes produce enough moisture to whiten the shellac, even under subsequent coats of varnish.

In kitchens, pantries, bathrooms, and, in general, in the whole service portion of a house, it is better to use varnish, as the application of water will be more general in these parts than in the main rooms.

Rubbing-Down. The rubbing-down of shellac or varnish is a protection against whitening, and for this reason, besides the gain in appearance, every coat, especially in finishing with shellac, should be rubbed down. This rubbing-down may be done with fine sandpaper, or haircloth, or curled hair, and the last coat may be treated in various ways, according to the finish desired. To obtain an eggshell gloss for the final surface, the last coat should be rubbed with pulverized pumice stone and raw linseed oil. For a dull finish, water instead of oil may be used with the pumice, and for a highly polished surface, a rubbing with pumice and water may be followed by polishing with "rotten stone" and water. Work that is to be polished should never have less than three varnish coats, but an eggshell gloss may be obtained with two coats.

Floor Finish. To obtain permanent wearing qualities in the finishing of floors is a troublesome matter. The elastic varnish which we have used for the standing finish requires a different treatment when subjected to the wear and tear of floors. Referring to the specifications, we find that the floors are to be stained as approved, and the oak, which is an open-grained wood, is to receive a coat of oil filler; this brings out the grain of the wood and the floor is then

ready to receive three or four coats of shellac, each sandpapered as before, and the last coat rubbed with pumice stone in oil or water to a dull finish. For floors of maple, birch, or any close-grained wood, the oil filler would be of no use and its place should be taken by extra coats of shellac. For the hard-pine floors of the kitchen, back halls, and bathroom, which are subjected to a great deal of use and more or less water, a satisfactory finish may be obtained by giving simply two coats of oil with turpentine dryer added to prevent the dust from sticking as it would to clear oil.

A finish less expensive than the shellacked finish for hardwood floors is obtained by using wax polish which is applied to the wood after the filling or, better, over one or two coats of shellac. This wax polish is a paste which enters the pores of the wood, dries in a few hours, and can then be polished with cloths, or by dragging to-and-fro over the floor weighted brushes, which are sold for the purpose. By keeping a brush and the wax at hand, any worn spots on the floor can be easily renewed and the whole kept looking well indefinitely.

A first-class job of finishing should never be hurried, but each coat should be thoroughly dry before the next one is applied. Varnish should be applied at a temperature of about 70 degrees Fahrenheit, and this temperature should be maintained until the drying is complete. Clean brushes should be used at all times, and a rising of dust in a room should be wet down and checked.

Miscellaneous Details. Besides the standing finish and floors, miscellaneous parts must receive the painter's attention. Pulley stiles of windows must be oiled, sashes drawn, exposed brass piping shellacked, and thresholds oiled or varnished. All of these minor details need the attention of the superintendent or they will be overlooked. Other than this, the supervision of the painting work involves mainly seeing that the best of materials are used. To this end it will be necessary to insist that all paints shall be mixed at the building, and that all materials are of the specified kind and are brought to the building in the original cases or kegs.

Wall Surface. *Tinting.* It will generally be found necessary to tint or fresco the ceilings and walls which are not covered with paper or hangings. This is a matter which needs careful workmen who understand the preparation and application of the colors.

Much depends upon the first or sizing coat, which should always be applied before tinting or frescoing of any kind is done.

Oil Paint. For the service portions of the house and the untiled walls of the bathroom, oil paint or some washable compound should be used. If oil paint, the walls should be sized and at least three coats of paint applied. Oil paint, unless stippled or otherwise "flatted", gives a shiny wall surface which is not so pleasing to look at as a flat coat, and besides shows the blemishes more. For this reason flat tints which can be washed have been put on the market, of varying composition, all designed to give a dull surface without the added cost involved in stippling or other treatment of oil paint. These are marketed under various names, usually suggestive of their "flat" qualities, and in a large range of colors, sample cards of which may be obtained of the manufacturers.

Glazing. *Common Glass.* It is usually the custom to send the sashes to the building all glazed, so that the superintendent needs only to see that the glass is whole and of the specified quality. Common window glass is called sheet or cylinder glass, and is rated as double or single thick, and as first, second, or third quality. Formerly all glass was imported from France or Germany, but American glass has come into general use in the greater part of the United States.

In the eastern States, window glass is still imported and it is customary to specify German glass for the best work. For lights up to twenty-four inches in width, single thick glass may be used; this is about one-sixteenth of an inch in thickness, while double-thick glass is about one-eighth inch.

The best quality of common American glass is known as AA, the second as A, and the third as B. Sheet glass is made by blowing the molten glass in a cylinder about fifteen inches in diameter. This is trimmed and cut longitudinally and heated until it can be opened out flat. Sheet glass always retains a vestige of its curvature. Between first and second quality glass it is difficult to distinguish except by practice, but defects or unevenness may be seen at once. Plate glass is always readily distinguished by its polish and its absolute freedom from imperfections of any kind.

Plate Glass. For lights more than five feet square, plate glass must be used. This may be obtained in three grades—French plate and two grades of American plate. French plate, and the first or

silvering quality of American plate, are used almost entirely for mirrors, while the second quality of American plate is used for glazing.

American glazing plate is made in one quality only, and is usually $\frac{1}{4}$ inch thick for ordinary sizes, but is necessarily thicker for large lights. It can be obtained in sheets as large as 12 by 17 feet. Plate glass is absolutely straight, being cast on a perfectly flat cast-iron table and rolled to the required thickness. The rough plate thus formed is carefully examined for flaws which are cut out, leaving as large a sheet as possible, which is polished. French plate may be distinguished from American plate by the color, when looked at endways; the French glass shows perfectly clear and white, while the American glass has a bluish color.

Crystal Plate. A kind of plate glass called crystal plate is made about $\frac{3}{16}$ inch in thickness. This is used for railway cars and in places where thin sashes must be used or a saving in weight is desirable.

Final Inspection. With the departure of the painter the house is usually complete, and ready for the architect's final inspection and acceptance. This inspection should be careful and thorough from top to bottom, and no certificate of acceptance should be issued, until the architect is satisfied that everything has been done which is actually called for or reasonably implied by the plans and specifications.

FRONT VIEW OF RESIDENCE OF WILLIAM V. CARROLL, OAK PARK, ILLINOIS
Tallmadge and Watson, Architects, Chicago

BUILDING SUPERINTENDENCE

PART II

CITY BUILDINGS

FOUNDATIONS

The requirements of city buildings, which are for the main part similar to the practices which we have already considered, are, nevertheless, in many essentials, distinct. In the first place, the circumstances of situation, soil, and surroundings differ from suburban or rural conditions. Instead of being able to establish our building to meet our individual tastes, we shall find that the sidewalk and yard levels are already established, and that in some localities the level of the cellars or basements is restricted. The lines of our building will also be determined, in a great measure, by fixed lines and restrictions, so that much more preliminary work will be needed to make the most of the existing conditions with which we find ourselves confronted.

Party Walls. Of great importance in laying out our building are the existing agreements with regard to party walls. In most cases it will be found that there has been signed an agreement relating to the construction and use of party walls. The usual arrangement is that the party who first builds shall build and pay for the wall, which is erected one-half on each side of the party line, and that the adjoining owner shall have the right to use and acquire the half of wall which stands upon his side of the line, by paying to the party who has already built, the cost of one-half of the wall as erected.

As buildings of different heights require walls of different thicknesses, it is usual to agree that no wall shall be primarily erected which extends more than 6 inches beyond the party line, so that if one owner desires to erect a building which will require a greater thickness than 1 foot for the party wall, he must erect all except 6 inches of the thickness of the wall upon his own land. While a party wall agreement will probably be a matter of record, which

can be looked up in the proper place, much time may often be saved by seeking some information on the spot.

If the land on either side of our lot is already occupied by a building, the conditions of the wall finish will be likely to afford data upon which we can work. If the finished brick or stonework covers apparently only one-half of the wall, leaving a surface of rough brick set back from the face or ashlar line, Fig. 122, it will indicate that the wall is a party wall, as it is the usual practice for each owner to stop the front of his building at the party line. If, on the other hand, we find the finished work covering the wall completely, Fig. 123, we may assume that the wall in question is not a party wall, but a wall built wholly upon the land of the adjoining owner. This evidence will be confirmed if, upon measuring the distance between the two side lines of the lot in question, we find it to agree with the figures upon the surveyor's plan with which we must be provided before laying out our own plans. The matter of party wall rights is, however, so important that it cannot be settled by mere observation, satisfactorily enough to permit building operations, and we shall, therefore, need to apply to our client for a copy of any agreements or restrictions, and proceed to plan and construct the new buildings in accordance with them.

Fig. 122. Finish at Party Wall

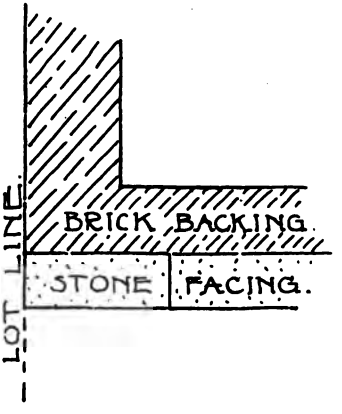


Fig. 123. Finish of Wall When Not a Party Wall

Knowledge of Soil Foundation Important. If the nature of the soil upon which we are to build is not known, we must have borings made to determine the composition at different levels. If two borings on opposite sides show about the same character, it will be sufficient evidence of general uniformity in the soil, but if these vary, then borings should be made

all around. Rock, clay, or gravel bottom will require only that our foundations shall be made wide enough to distribute the weight of the building, with its contents, over an area sufficient to sustain it. The bearing power of rock varies from 10 to 30 tons per square foot, of dry clay from 4 to 6 tons, of gravel from 8 to 10 tons. If, however, the soil consists of mud or filled land, such as is found on the borders of lake or ocean, it will be necessary to drive piles, upon which the footings shall be supported.

Pile Foundations. Piles may be of wood, cast iron, concrete, or steel, but for ordinary buildings they are usually made from the trunks of trees, and should be straight and sound and, for heavy buildings, at least 8 inches in diameter. Spruce, hemlock, Georgia pine, and oak are the principal kinds of wood used for piles. The customary method of driving piles is by repeated blows from a block of iron called the hammer, which works up and down between the uprights of a machine called a pile driver.

Piles should be spaced not less than 2 feet, nor more than 3 feet, on centers, and they must be cut off below low-water mark. The level at which piles are to be cut off is given by the building laws of most large cities and is established at a point which insures the pile being at all times under water. Under these conditions the piling will be subject to no decay, whereas alternate conditions of moisture and dryness soon result in the rotting of the piles.

Supervision. The superintendence of piling consists first in an examination of the piles as they are delivered, to see that they are of the requisite length and diameter, and sound and straight. The lines of the building must be carefully established, and small stakes driven to fix the position of every pile. This should be verified by the superintendent according to the piling plan furnished. When the actual driving of the piles begins, there should be kept a complete record giving the length of pile, the number of blows, and the distance which the pile has sunk at each of the last ten blows. From this data the bearing capacity of the pile may be computed.

Besides keeping this record, the pile should be carefully watched while being driven, to see that it does not get out of line and that the head does not "broom" or split excessively. If there is danger of this, the head of the pile should be bound with a wrought-iron strap or a cast-iron cap. When the piles have been driven,

trenches wide enough to accommodate the stone levelers must be excavated and kept free from water to a depth sufficient to allow the sawing-off of the piles at the required height. This is usually done by means of a cross-cut saw operated by two men, and the

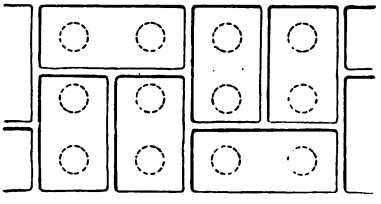


Fig. 124. Capping for Three Rows of Tiles

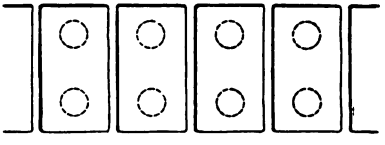


Fig. 125. Capping for Two Rows of Tiles

tops must be cut off at a level with each other. Piles exposed to tidewater are usually driven with the bark on.

Footings of Stone and Concrete. Whether the bearing is piles or the natural earth, the bottom of the foundation usually consists of large stones or of concrete. If three rows of piles are used, they may be covered as shown in Fig. 124. Two rows of piles are generally capped by a series of levelers laid across the trench, Fig. 125. A footing on earth will be laid in a like manner, of the width made necessary by the load to be borne and the nature of the soil. These

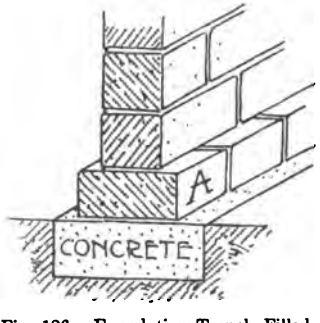


Fig. 126. Foundation Trench Filled with Concrete Footing

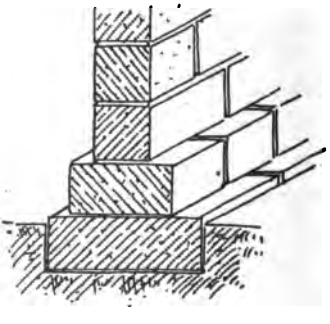


Fig. 127. Section of Foundation Using Stone Footing

wide footings which may be of stone, brick, or concrete, are designed to spread the weight over a large area and also to add stability to the wall.

For nearly all buildings on solid ground, concrete footings are probably the best, and in many cases concrete capping for piles

may be used to advantage. Trenches for the footing may be dug below the regular excavation and of the exact width required, and into this the concrete may be tamped, Fig. 126. If this concrete is much wider than the wall over it, a stone leveler may be placed on the top, as shown at *A*.

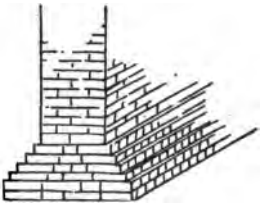


Fig. 128. Foundation Footing of Brick for Light Building

If preferred, stone footings of a similar character may be used, Fig. 127, and for light buildings, where stone is hard to obtain, brick footings may be used. If the footing is brick, the offsets should never be more than one-quarter of a brick, and the outside work should be all headers, with a double course at the bottom, Fig. 128. This course should be of hard-burned bricks, thoroughly wet if the weather is dry, and should be laid in a bed of mortar spread on the bottom of the trench.

Too much care cannot be taken in making sure of a good foundation. If important footings are made of concrete, an inspector should be on hand during working hours, to see that the concrete is mixed in proper portions, that it is put in to the full thickness directed, and tamped and leveled. The trenches must be kept free from water until the cement has set, for the water would separate the cement from the sand, and render it utterly worthless. If the footing is of stone the presence of a few inches of water will do no harm, but the footing must then be bedded in firm sand or gravel instead of cement.

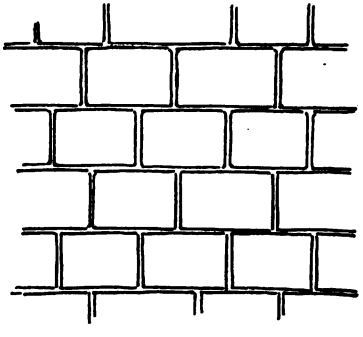


Fig. 129. Block Stone Wall

Foundation Walls. *General Specifications.* The foundation walls of a city building above the footing course are sometimes built of stone and sometimes of concrete, and brick may be used to advantage for the party wall where there is to be a cellar both sides. For the heavy outside walls of buildings three or more stories in height, it will be necessary to use concrete or block stone. The latter are stones roughly fashioned to

dimension and are generally from 18 inches to 2 feet in height, by the full width of the wall, Fig. 129. Being brought nearly even and square, not much mortar need be used, and this should be of clear cement and sand below the grade line.

Rubble Walls. For a foundation of a lighter character, rubble stone may be used. This consists of stone split from a ledge, the only preparation being to break it up with a stone hammer and to square one edge and face. As these stones are irregular in shape and thickness, considerable mortar will have to be used, and the character of the mortar and the filling of voids will need special attention. An important element in the strength of a rubble wall is the bonding or the lapping of stones over each other. The stones should be laid in irregular courses and leveled off to a horizontal joint about every 2 feet, and a bond stone should be put in at intervals of 4 or 5 feet. Most city laws require a certain proportion of bond stones, and if nothing is said, a through bond stone should be inserted into every 5 or 6 square feet. Care must be taken that the stones are bonded also in the direction of the length of the wall, so that no vertical joints may appear running through three or four courses. Outside of the bonding, other points in laying the stones must have our attention. All the stones must be set as nearly as possible on their natural bed, that is, with their split surfaces horizontal. Angles and corners must be carefully laid with large stones bonding across each way, as in Fig. 130.

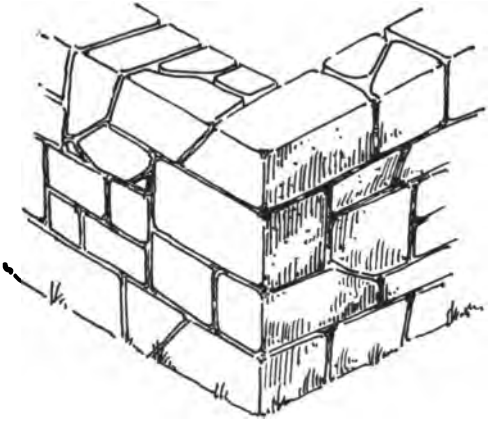


Fig. 130. Proper Bonding of Corner of Rubble Wall

Block Stone Walls. With a heavy foundation wall of block stones, where each stone is of the full thickness of the wall, the main care will be to obtain a good bond, with level and plumb joints. Openings for pipes should be left when the walls are built,

as it may be difficult to break an opening after the walls are carried up.

Use of Derricks. All of the stones which are suitable for the heavy walls which we have described, are large and will require the use of derricks in the handling. If the building is to be one of great size or height, a system of three or four large derricks will probably have been started, swinging from some central scaffold, and guyed to this and to each other. For a building of but three or four stories, however, the builder will probably use a series of smaller derricks, each supported by its own guy ropes. The superintendent should make sure that the ropes are strong and not frayed, that the mast and boom are neither cracked nor sprung, and that the running gear is strong and shipshape. The securing of the guy ropes is a very important matter, and should be watched by the superintendent. Although it belongs to the contractor to do, a careful inspection by the architect will doubly insure the safety of all concerned. In suburban or out-of-town work the guys are usually secured to a convenient tree, and this should be a young or evidently sound tree; if posts have to be put down, as is necessary in the city, they should be set deep in the ground with the earth well tamped in again. The guys must be at all times drawn taut, as a loose guy will be given a sudden and dangerous strain if a heavy stone is swung around so as to bring its weight upon it.

The derrick allows heavy stones to be carefully set, and this will be especially noted in the handling of the capstones for the piles. These will have been selected for an even bed and can be shifted until they rest immovable on the piles. In bedding, the heavy stones may be held suspended over the place where they are to lie while an even bed is being prepared, and, if necessary, the stone may be lowered and then raised again before the final setting, so that the impression will show where the bed needs fitting.

Thickness of Walls. The thickness of foundation walls in all large cities is controlled by laws which in general require that walls to a depth of 10 or 12 feet below the ground shall be, if brick, 4 inches thicker than the walls above; and if stone, 8 inches, with an increase of 4 inches for every ten feet below this. In clay, which is more seriously affected by frost than gravel, it is a good plan to build foundations with a batter on the outside of 6 to 12 inches,

as in Fig. 131, so that any movement of the earth will readily free itself from the wall, which should be made smooth on the outside with cement.

Areas. Areas are often required, to give light or access to basements, and these need a retaining wall to keep back the earth. Stone should be used for areas of any size, and, in excavating, the bank should be disturbed as little as possible and refilled carefully. If the area is not more than 6 or 7 feet deep, a good wall of a uniform thickness of 20 inches will be sufficient, but if the area is deeper, the wall should be made wider at the bottom and battered. If the wall is more than 10 feet long, cross-walls or arches should be built to connect with the main building. The bottom of the area should be carried at least 6 inches below the sill of window or door, and covered with stone flagging, brick laid in cement, or a concrete bottom made with a small cesspool, with cover, connected with the main drain.

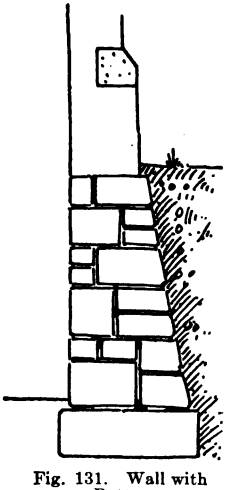


Fig. 131. Wall with Batter

Vaults. The space under the sidewalks and entrance steps or porches is often utilized for coal or general storage purposes. This requires a wall at the street line which is heavy enough to sustain the pressure of the street and the weight of the sidewalk. If it is possible to divide this space so that the partition walls can be run back to the main building about every ten feet, the construction can be simplified; but if an open space is required, a very heavy wall must be built at the street line, and from this wall to the building, steel or concrete beams laid, which will buttress the top of the street wall and support the weight of the sidewalk as well. Brick arches may be turned between the steel beams and leveled up for the sidewalk, or a concrete or flagstone sidewalk may be constructed over

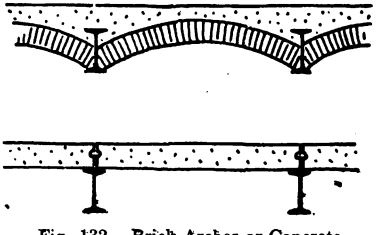


Fig. 132. Brick Arches or Concrete Slabs for Sidewalk Construction.

them, Fig. 132. If brick arches are turned, to be covered with an ordinary brick paving, the tops of the arches should be coated with hot asphalt. Any of the modern forms of fireproof floor construction may be used for the sidewalk covering, finished with concrete or granolithic surface.

Methods of Waterproofing. As a protection against dampness, the outside of all cellar and vault walls in wet situations should be coated with hot asphalt or Portland cement. Asphalt, applied while boiling hot in two or more coats from top to bottom, is considered the more lasting if the ground is very damp, as Portland cement is affected by frost and is easily cracked by settlement of the walls, while asphalt, having considerable elasticity, remains sound and tight. Coal tar is sometimes used, but that gradually becomes brittle and crumbles away.

Integral Method. The so-called "integral" method of waterproofing has been developed to a high degree of efficiency. This consists of the application of a preparation which penetrates or adheres to old or new masonry or concrete and forms a bond that withstands a hydrostatic pressure limited only by the strength of the masonry to which it is applied. The most effective of these compounds contains a bituminous material, chemically prepared so that it may be combined with water and used in proper proportions in mixing the cement instead of plain water. This mixture is applied to the walls in three coats of about $\frac{1}{4}$-inch thickness each. For floors, a single coat of an inch thickness may be applied.

Membrane Method. Another method of waterproofing is the membrane method, in which a thin layer of water-resisting felt or other fabric is held in a position to withstand the water pressure by the weight of concrete or other masonry laid upon or against it.

Simpler Methods. For work above ground where the resistance is against a driving rain or continued soaking without a water pressure to contend with, simpler methods may be used, such as the application of a transparent waterproof coating to the exterior masonry, or an adhesive coating on the back of the wall, which may be plastered upon if desired. Compounds are also prepared which may be mixed with the mortar in which the masonry is laid, in cases where the materials of the wall are nonabsorbent, or mixed with the cement plaster in the case of plastered exteriors.

BRICKWORK

In the superstructure of a city building of ordinary height, say up to five or six stories, except in the so-called skeleton construction, we shall usually find that brickwork forms the greater part of the wall. The face is often finished with stone, either rough or cut, but the backing, and frequently the face as well, is usually constructed of some form of brickwork, so that bricks of one kind or another are probably more extensively used in the construction of city buildings than any other material.

BRICKS

Essential Qualities. The advantages of bricks over stone are that the bricks are practically indestructible, either from the action of fire or the elements, and that they are less expensive and more easily handled. Good building bricks of the different kinds should be sound and free from flaws and stones or lumps of lime, uniform in size, and square, hard, and not too absorbent. A good hard brick will ring distinctly when struck by another brick or by a trowel, and it should not absorb more than 10 per cent of its weight in water. In selecting bricks from a quantity delivered, the hard and usually the darker bricks should be culled for the outside walls, while the lighter bricks should be used for backing and the inside courses.

Varieties. It is customary to speak of common bricks, face bricks, etc. Let us pause and consider just what is meant by these terms. *Common bricks* include all rough, unpressed bricks which have had no special care taken in their manufacture. These, according to their position in the kiln, become burned to varying degrees of hardness. *Arch bricks* are those which from being near fire become burned to a great degree of hardness, and are often warped, vitreous, brittle, and weak. *Red bricks*, which compose the bulk of the kiln, are those burned with an even and moderate temperature. *Salmon*, or *soft bricks*, are those which are found at the top of the kiln and are usually underburned. They are good only for inside courses and for lining chimneys.

Face bricks, in which general term are included pressed bricks, molded bricks, etc., are made or re-pressed in a dry-press machine. Face bricks are more expensive than common bricks and are gen-

erally used for facing exterior walls, for fireplaces, and for molded work. *Enameled bricks* are bricks whose faces are covered with a coat of enamel of selected color. The true enameled brick is a very expensive article, and most of the bricks called by this name are glazed bricks, the difference being that the true enamel is fused into the clay and is opaque in itself, while the glaze is formed by coating the surface with a colored film and covering this with the transparent glazing. This film is apparent on chipping off the glazing, while the true enamel shows no line between the body of the brick and the surface. Both glazed and enameled bricks are impervious to moisture and are excellent for the facing of halls, courts, or wherever a light, clean, and waterproof surface is desired.

In addition to the kinds already mentioned, special bricks are made for special purposes, as fire bricks for furnace lining, etc., which are open-grained or porous to admit of a rapid loss of heat; and paving bricks, which are burned to vitrification to withstand the wear of travel and the action of frost.

Sizes. The sizes of bricks vary with the maker and with local customs. Common bricks in New England average $2\frac{1}{4}\times3\frac{3}{4}\times7\frac{3}{4}$ inches; in the western States, about $2\frac{1}{2}\times4\frac{1}{8}\times8\frac{1}{2}$. Face bricks are more nearly uniform in size, and average about $2\frac{3}{8}\times4\frac{1}{8}\times8\frac{3}{8}$ inches. Pressed bricks are also made in a thinner pattern, $1\frac{1}{2}\times4\times12$ inches, a style known as Roman brick.

MORTARS

All mason work below ground should be laid in cement mortar, and all arches or heavily loaded piers as well. In many city laws the use of cement mortar is required up to a certain proportion of the height of the wall. Cement mortar of some kind should be used for setting cornice stones and wherever the work is especially exposed. For all work under water, for large arches, and for tops of chimneys, Portland cement should be used, and Portland cement may be mixed with Rosendale to make a strong, quick-setting mortar. Portland cement and lime may be mixed to give a strong light-colored mortar which is much used in England for face brickwork.

Sand. The proportion of sand in mortar should vary with the kind of cement and the use for which the work is intended. With Rosendale cement, the proportion of sand should not exceed 3 to 1,

and for piers, 2 to 1. Portland cement may contain sand in the proportion of 4 to 1, and lime mortar 3 to 1. The object of using sand in mortar is to prevent too much shrinkage, and also to secure a material cheaper than lime or cement. Its functions are mechanical rather than chemical. Sand strengthens lime mortar by supplying a base to which the particles of lime adhere more firmly than to each other, but its presence in cement mortar is a weakness. In all cases a thorough mixing is essential, the object being so to intermingle the particles that no two grains of sand will lie against each other without a film of cement between. The cement and sand should be mixed dry, the process being to spread them in layers and then to turn and work the mass until it is thoroughly mixed, when water is added in sufficient quantity to obtain mortar of the desired thickness.

If too much sand is added, the mortar will stick to the trowel and will not work easily. The superintendent should become familiar as soon as possible with the appearance of good mortar so that he can tell readily whether too much or too little sand has been added. If the mortar slides easily from the trowel it is usually of the right proportion. In ordinary practice, the lime and sand are mixed as soon as the lime is slaked and allowed to stand until needed, but it is better not to add the sand until the mortar is wanted. Coarse sand makes a stronger mortar than fine sand; fine, loamy sand, although it works more easily than sharp, coarse sand, does not make a sufficiently strong mortar.

Lime. Lime is now manufactured in nearly all parts of the country, but differs in character in different localities. In using a lime which is not already familiar, some inquiry should be made as to its properties, especially if used for plastering. Good lime should, in general, have no cinders or clinkers, should contain less than 10 per cent of impurities, and should be found in large lumps which will slake readily in water, making a soft paste, free from residue or "core"; it should, further, completely dissolve in soft water. Slaked lime, or "lime putty" as it is commonly called, will keep indefinitely if protected from the air so that it does not dry. This protection is usually secured by covering the lime with sand in the bed in which it is slaked. Lime before slaking will absorb moisture from the air and become air-slaked; this destroys its strength, and

care should be taken that all lime is carefully sheltered from dampness until used.

Setting and Durability. Lime mortar does not possess the setting quality of cement, though it gradually hardens by exposure to the air. Common lime mortar does not harden under water or in damp situations, but in dry places where there is ample exposure to the atmosphere, it will set hard enough for all ordinary uses of brickwork, except arches and piers and structures where excessive loads may be applied.

Hydraulic Lime. Some limes after burning contain enough clay or silica to acquire the property of setting under water. They are called hydraulic limes. This lime, formerly imported from England and France, is now employed to a very slight extent, as its special quality is more easily and profitably obtained by the use of the abundant, easily made cement.

Cement. Cement may be divided into two classes—natural cement and artificial cement.

Natural Cement. This is obtained by burning limestones which contain a large proportion of clay. A powder is formed which, when mixed with water, sets quickly either in air or in water. Natural cements are made in many localities throughout the country, Rosendale cement being probably the best-known brand, and one which is usually of good quality and easily obtained.

Portland Cement. Of artificial cements, the most widely used is Portland cement; this is of English origin and derives its name from the resemblance of a troweled surface to Portland stone, one of the most common building stones of England.

Portland cement is made by combining in proper proportions carbonate of lime, clay, silica, and iron. This mixture is ground and then burned into a heavy vitreous clinker, a dark porous mass which resembles lava. This clinker is crushed and ground again to a powder and run through fine sieves to make the finished product. It is then seasoned for a time in storage and put into barrels or bags for shipment, one barrel containing 376 pounds net. When shipped in bags the weight is 94 pounds per bag, 4 bags being equal to 1 barrel. A bag of loose cement is about equivalent to 1 cubic foot, and this is the most convenient form for ordinary uses, if care is taken to keep the cement in a dry place.

Portland cement does not, in general, set so quickly as natural cement, but it possesses greater strength, and it has now practically superseded the natural cements formerly extensively used. While Portland cement is of the greatest service in all kinds of concrete construction, it also forms an important ingredient of the mortar with which brick, stone, and other forms of masonry are laid. For this purpose there is upon the market a grade of cement known as sand cement, in which a certain proportion of sand is mixed with the powder and the whole ground to the fineness of cement; this requires less sand in the final composition of the mortar and is productive of satisfactory results. Another prepared cement of a nature similar to Portland cement is known as Lafarge cement, and is useful in setting limestone or marble, since it does not stain like other cement.

Tests. Some idea of the quality of cement may be obtained by observing carefully its appearance upon opening the cask or bag. With natural cement, the darker brown colors indicate, in general, stronger qualities; too dark a color, however, may indicate in an unfamiliar brand the presence of coloring matter, usually lampblack. This may be detected by putting some of the cement into a glass of water, when the lampblack, if present, will separate as a black scum. With Portland cement, a clear gray or bluish color is to be preferred, as a brown color is given by an excess of clay; too strong a bluish cast, however, marks the presence of too much lime. Further tests of cement for ordinary work may be made as described in Part I, but in important engineering construction in which Portland cement is used, the cement should be subjected to careful tests for activity, soundness, and strength, both unmixed and mixed with sand.

To obtain the best results the superintendent should, in general, choose a fine, well-burned cement of average specific gravity, and, for important work, test it frequently. Mixed with sand that has passed a careful scrutiny for cleanness and regularity, such cement should give a smooth and strong mortar.

Protection in Laying. Whether lime or cement mortar is used in the building of a wall, it should be kept at all times protected from the weather until the mortar has had time to become thoroughly set.

BUILDING OF WALLS

Laying Brick. In erecting a brick building it is necessary to lay the carefully chosen bricks upon each other, with a bed of some kind of mortar between. Ordinary brickwork is laid in common white-lime mortar, but for greater strength and durability there is often added a proportion of cement, and for brickwork below ground, cement mortar only should be used. The thickness of the joints will vary from $\frac{3}{16}$ inch to $\frac{3}{8}$ inch, according to whether the joint is to be concealed or made a feature of the work.

The laying of the bricks should be carefully watched, as there is a tendency on the part of many masons to slight this work. The following general observations are given:

Bricks should not be merely laid, but every one should be rubbed and pressed down in such a manner as to force the mortar into the pores of the bricks, and produce the maximum adhesion; with quick-setting cement this is still more important than with lime mortar. For the best work it is specified that the brick shall be laid with a "shove-joint", that is, that the brick shall first be laid so as to project over the one below, and be pressed into the mortar, and then be shoved into its final position. Bricks should be laid in full beds of mortar, filling end and side joints in one operation. This operation is simple and easy with skilful masons, if they will do it, but it requires persistence to get it accomplished. Masons have a habit of laying bricks in a bed of mortar, leaving the vertical joints to take care of themselves, throwing a little mortar over the top beds and giving a sweep with the trowel which more or less disguises the open joint below. They also have a way, after mortar has been sufficiently applied to the top bed of brick, of drawing the point of their trowel through it, making an open channel with only a sharp ridge of mortar on each side (and generally throwing some of it overboard), so that if the succeeding brick is taken up, it will show a clear hollow, free from mortar, through the bed. This enables them to bed the next brick with more facility, and avoid pressure upon it to obtain the requisite thickness of joint. Neglect in wetting the brick before use is the cause of many of the failures of brickwork. Bricks have a great avidity for water, and if the mortar is stiff and the bricks dry, they will absorb the water so rapidly that the mortar will not set properly, and will crumble in the fingers when dry.

Mortar is sometimes made so thin that the brick will not absorb all the water. This practice is objectionable; it interferes with the setting of the mortar and particularly with the adhesion of the mortar to the brick. Watery mortar also contracts excessively in drying (if it ever does dry), which causes undue settlement and, possibly, cracks or distortion. The bricks should not be wet to the point of saturation, or they will be incapable of absorbing any of the moisture from the mortar, and the adhesion between the brick and mortar will be weak. The common method of wetting brick by throwing water from buckets or spraying with a hose over a large pile, is deceptive; the water reaches a few bricks on one or more sides and escapes many. Immersion of the brick for from three to eight minutes, depending upon its quality, is the only sure method to

avert the evil consequences of using dry or partially wet brick. Strict attention must be paid to have the starting course level, for the bricks being of equal thickness throughout, the slightest irregularity or incorrectness in it will be carried into the superposed courses, and can only be rectified by using a greater or less quantity of mortar in one part or another, a course which is injurious to the work. A common but improper method of building thick brick walls is to lay up the outer stretcher courses between the header courses, and then to throw mortar into the trough thus formed, making it semi-fluid by the addition of a large dose of water, then throwing in the brickbats (sand and rubbish are often substituted for bricks), allowing them to find their own bearing; when the trough is filled, it is plastered over with stiff mortar, and the header course laid and the operation repeated. This practice may have some advantage in celerity in executing work, but none in strength or security.

A modification of this latter practice, in which the bricks are laid dry and grouted with moderately thin mortar *in every course*, may be successfully used in weather when there is no danger of freezing, and it will make solid work. This is especially suited for footings and foundations of brick where it is necessary that every joint shall be filled, as the thin grouting is more to be depended upon for that than is the average mason.

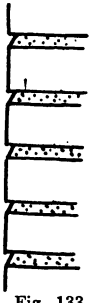


Fig. 133. Struck Joint

Joints. For inside walls which are to be plastered or otherwise concealed, the joints may be simply cut off flush with the trowel, but where the walls are exposed, the joints should be *struck*, Fig. 133. This consists in pressing or striking back with the trowel the upper portion of the joint while the mortar is soft, so as to form a sloping surface from the bottom to the top. *Keyed joints* are formed by running an iron jointer with round or V-shaped edge along the center of the flush joint, giving it a depression and hardening the mortar by the pressure, Fig. 134. *Ruled joints* are made by holding a straightedge under the joint and running the jointer along, making a perfectly straight joint.

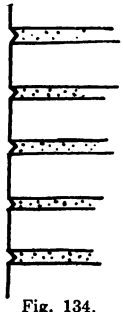


Fig. 134. V-Joint

Bonding. The strength of a brick wall depends not only on the bricks, the mortar, and the workmanship, but on the assembling of the different members, the bond or arrangement adopted for tying together the separate parts and for distributing the effects of concentrated loading. The common bonding consists in laying every fifth or sixth course of bricks at right angles to the direction of the wall,

Fig. 135. These courses are called header courses and serve to tie the wall together. Where the wall is faced with pressed brick

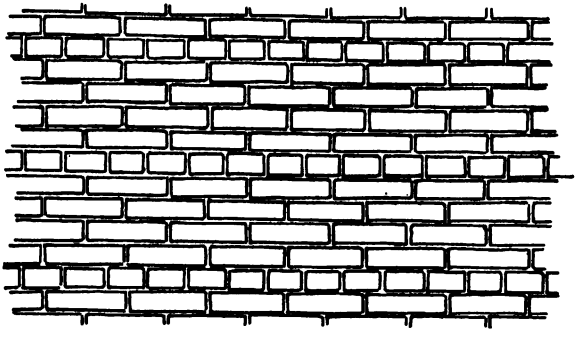


Fig. 135. Common Method of Bonding Brick

and the regular occurrence of header courses would not look well, the face work is tied to the backing by clipping off the back

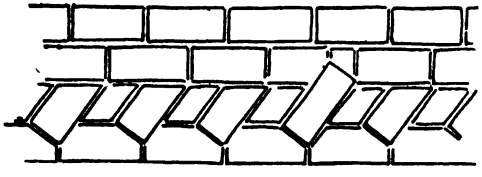


Fig. 136. Plan View of Wall with Pressed Brick Facing, Showing Diagonal Bonding Course

corners of the face bricks, and inserting a course of diagonal headers, Fig. 136. Galvanized steel ties of patented manufacture are

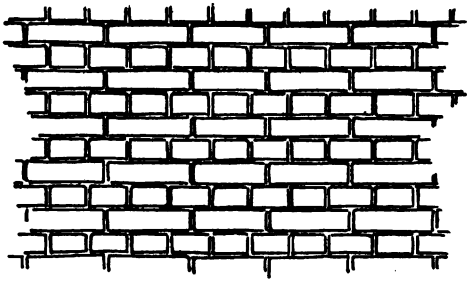


Fig. 137. English Bonding Method

extensively used in the East for this purpose, and have proved effective. English bond, the method in vogue in England, consists

of alternate courses of headers and stretchers, Fig. 137. Flemish bond, Fig. 138, consists of alternate headers and stretchers in each course. This bond is sometimes employed effectively in facings of common brick by inserting blackened headers, and it is sometimes used for every fifth course of face work instead of the diagonal headers. The bonding of angles is an important matter, and, in

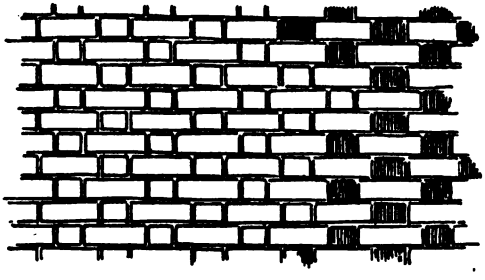


Fig. 138. Flemish Bonding Method

addition to the regular bond, most city laws require that the corners shall be tied with iron straps or bolts. In joining new work to old, however, direct bonding should be avoided for fear of unequal settlement, and some such method as that shown in Fig. 139 should be adopted.

Construction in Freezing Weather. To obtain satisfactory results, bricks should never be laid in freezing weather. If the temperature is much below 40° F. during the day, so that it is likely to freeze during the night, salt may be mixed with the mortar and the top of the wall well covered with boards and straw; and if the upper courses are found to have frozen over night, they must be taken down and relaid, as the alternate freezing and thawing will materially damage the strength of lime mortar and will entirely ruin mortar made of natural cement of the Rosendale type. The following suggestions for the use of cement mortar have been given:

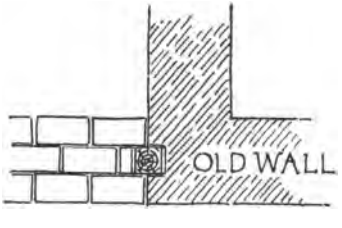


Fig. 139. Joint of New and Old Work

Mortar made of one part of Portland cement and three parts of sand is entirely uninjured by freezing and thawing. If it is absolutely necessary that brickwork should be laid in freezing weather with natural cement mortar, it may be done by mixing the mortar with water to which salt has been added in the

proportion of 1 pound of salt to 18 gallons of water, when the temperature is at 32° F.; for each degree of temperature below 32, add 3 additional ounces of salt. Mortar mixed with such a solution does not freeze in ordinary winter weather, and hence is not injured by frost.

In addition to this, the bricks should be warmed to remove any ice or frost. These methods may be used in emergencies, but the laying of bricks in freezing weather is not to be recommended.

Thickness of Walls. No practical rule can be laid down for the thickness of brick walls, as their crushing strength, which is usually the only direct strain applied, is generally, except in the case of small piers, a minor consideration. In all large cities the minimum thickness is fixed by law, walls of mercantile buildings being heavier than the walls of buildings used for living purposes; in no case is it advisable that party walls should be less than 12 inches. Exterior walls for a building of five stories should be not less than 20 inches in the lower story and 12 inches in the upper story. These dimensions apply to stories of ordinary height with spans of not more than 25 feet, or more than 25 feet without a pier. Walls which contain 33 per cent of openings should also be made thicker.

In the case of bearing walls—those which carry besides their own weight the weight of floors and roofs which bear upon them—. the thickness must be necessarily increased as the height of the building is increased, and they must be strong enough to brace the building against lateral forces, such as wind pressure, and the vibrations from external or internal sources.

Curtain walls—that is, those built between steel or iron columns. or between piers, which carry no loads except their own weight—have need of a thickness only such as to protect the outside of the building and give support to walls above.

In the case of skeleton construction, which has all its walls as well as other parts of the building supported by steel or iron columns, the masonry needs to be of just sufficient thickness to protect the building and the frame against the elements, unless these walls are depended upon for stiffening and bracing the building. The exterior walls may be of brick, concrete, terra cotta, or other fire-resisting material, depending in a measure upon the location, custom, experience of builders, and the influence of union labor in various localities.

The walls of each succeeding story in a skeleton frame will be supported independently and may be considered as curtain walls. At the present standard prices of materials, a building for ordinary floor loads can be erected eight stories high with continuous bearing walls of masonry, more cheaply than with piers and curtain walls or skeleton construction. If, however, the extra land area which the thicker bearing walls require is of value enough, it will be economy to use skeleton construction for six-, or even five-story buildings, depending largely on the character and location of the building.

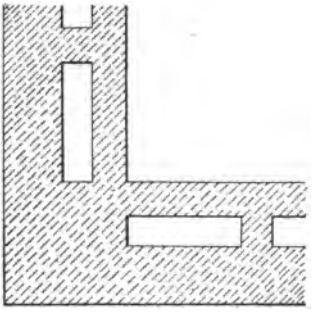


Fig. 140. Typical Hollow Wall with Brick Headers

Hollow Walls. To overcome the tendency of a solid brick wall to transmit heat, cold, and dampness, hollow walls are often constructed. A given number of bricks built as a hollow wall will make a more stable wall than will the same number of bricks built as a solid wall, and will gain besides the advantage of the air space. Nearly all building laws require the same amount of brickwork in hollow walls as in solid walls, independent of the air space, so that there is a loss of space which must be taken into account in city building.

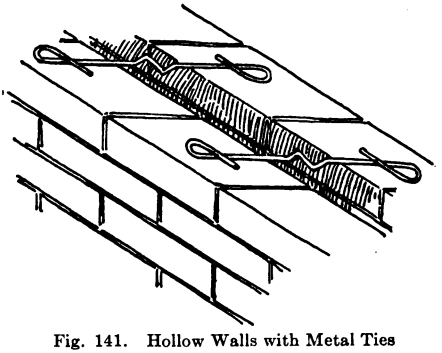


Fig. 141. Hollow Walls with Metal Ties

An important consideration is the bonding of the two portions of a hollow wall so that each will help to sustain the other. The usual method has been to do this by means of withes or headers of brick extending across the air space, Fig. 140, but these permit the moisture to pass from the outer to the inner shell, and also allow the mortar dropped from the higher portions of the wall to collect and partially fill the space. A more effective method of bonding is by means of a metal tie, either of steel wire or of iron, which should be made with a dip in the center to allow any moisture that may come from the outer wall to drop

off without being communicated to the inner wall, Fig. 141. These ties should be either galvanized or dipped in hot asphalt. It is a good plan to provide for a circulation of air through the space between the walls, by leaving openings in the basement and in the attic where possible. Hollow bricks are sometimes used for the inside course of exterior walls, but while they are partially successful in excluding moisture they do not take the place of a hollow wall.

Veneered Walls. In some localities, dwellings and light mercantile and public buildings are built with a frame of studs and boarding, veneered on the outside with 4 inches of brick. In such construction the strength of the building lies in the frame, and the superintendent should see that this is built and braced in the best manner, with all material of well-seasoned stock. Over the boarding, tarred felting should be placed, and an inch away from this, the 4-inch wall, tied at short intervals to the wooden wall, as shown in Fig. 142. A metal tie such as at *A* may be used, or the patented tie *B*, which is better.

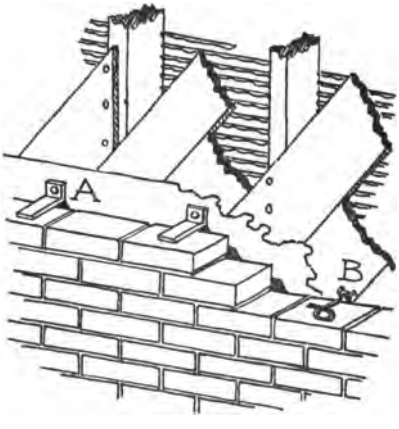


Fig. 142. Method of Bonding Brick Veneer

As moisture will collect in the air space behind the veneer, the ties will be better if given a drip, as for hollow walls, and a small drain may be laid at the top of the foundation wall, connected with the cellar by pipes for drip and ventilation.

Wood in Brick Walls to Be Generally Avoided. The combination of masonry and woodwork is not to be recommended in general, and should be used only as a matter of economy. Wood in the structure of brick walls may be sometimes necessary, but it should be avoided where possible. Wooden lintels were formerly used to a considerable extent, but they are objectionable for many reasons. Besides the fact that they are combustible, there is the difficulty of obtaining dry beams of the large size required, and the shrinkage is pretty sure to make a crack at some time, Fig. 143. Wooden plates should not be inserted in the wall for a level bearing of floor timbers,

as their shrinkage will leave the bricks above unsupported. Wooden lintels may be used under arches to form a square opening, but the arch should always spring from the solid wall beyond the lintel in order to relieve the latter from the load above, Fig. 144. Wooden strips are sometimes built into the walls for a nailing for furring and finish, but they should be thin enough to lie in the joint; wooden bricks, often used for nailing, by their shrinkage will become loose, besides weakening the walls. A better way is to use a strong mortar into which the nails of the furring strips may be driven, or, in special work, to set in porous terra cotta blocks for nailings.

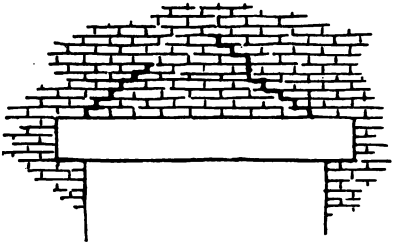


Fig. 143. Wood Lintels Usually Produce Cracks in Brick Walls

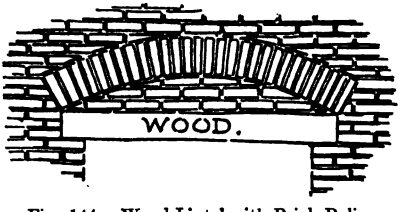


Fig. 144. Wood Lintel with Brick Relieving Arch

Wall Plugs and Inserts. For high buildings or walls subjected to heavy loads, the use of Portland cement for all kinds of masonry produces such hard mortar in the joints that the method of nailing the furring strip to brick or stone walls is not wholly successful. To meet this condition, metal plugs may be obtained in a variety of patterns, all designed to provide an orifice into which nails may be driven, the metal being corrugated or roughened in some way to grip the nail, Fig. 145.

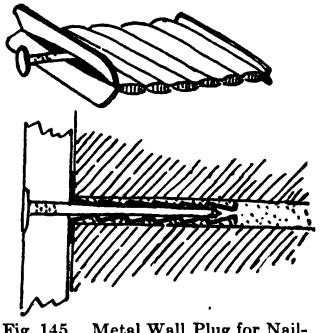


Fig. 145. Metal Wall Plug for Nailing in Brickwork

Of a similar nature are the different sorts of inserts placed in the concrete to receive the bolts or screws which may be necessary in the construction. These inserts consist of sockets or spiral members which are fastened in position to the forms before the concrete is poured.

The superintendent should carefully examine and verify the position of both plugs and inserts, as faulty alignment makes the plug or insert worse than useless.

Arches. In the erection of brick walls, special care should be given to the construction of arches which are necessary to span the openings. Arches should, in general, be laid in cement mortar. The two principal forms of arches in brickwork are the *rowlock arch*, where the bricks are laid in concentric rings of headers, Fig. 146, and the *gaged arch*, where the bricks are cut and bonded on radial lines, Fig. 147. For arches of large spans the bricks are often laid in rings of stretchers, Fig. 148, and, if the span is very large, these

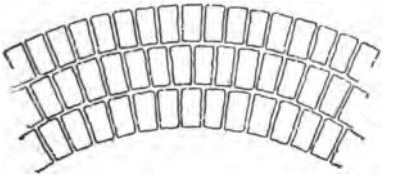


Fig. 146. Rowlock Arch

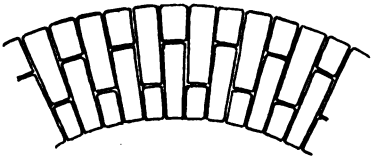


Fig. 147. Gaged Arch

may be strengthened by bonding in headers, as in Fig. 149. An important point in the use of arches is to see that each abutment contains sufficient masonry to support the thrust of the arch; tie rods should be freely used in case of any doubt, and the arches of large span should spring from stone skewbacks carefully cut to radial lines, Fig. 150.

Cleaning Walls. When a piece of brickwork is completed, the exterior needs to be cleaned of mortar stains and discolorations.

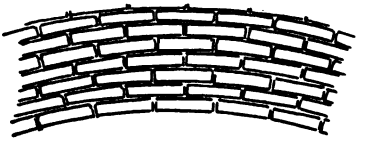


Fig. 148. Arch of Stretchers

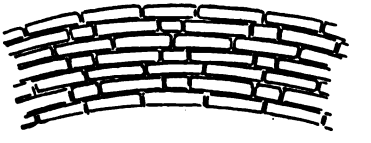


Fig. 149. Bonded Stretchers in Arch

This is done by applying a dilute solution of muriatic acid to the wall, using a scrubbing brush, and then washing with clear water to remove all traces of the acid. After this the wall is often given a coat of linseed oil cut with turpentine. At this time, also, all bad joints are pointed, the spaces under window sills are filled, the joints of the stonework pointed, and the wall left whole and clean.

Waterproofing Walls. Brick walls in exposed situations are often treated with some substance to render them waterproof. One

of the most successful processes is known as the *Sylvester process*, and consists in applying two washes to the walls, one composed of Castile soap and water, and the other of alum and water. These applied alternately generally render the work impervious to moisture. Several patented solutions are now upon the market, each of which is warranted to furnish full protection.

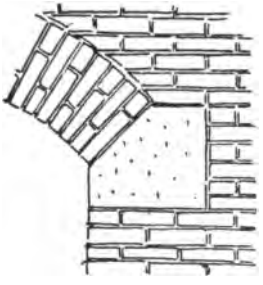


Fig. 150. Stone Skewback

Preventing Efflorescence. Very disagreeable and very common is the white efflorescence which often appears upon the face of the bricks, due to the salts of soda and potash dissolved by the water and left on the surface by evaporation. The Sylvester solution, applied in the same manner as for waterproofing, is a preventive of this, and the danger may be diminished by using stronger cement in the face joints.

Making Repairs. In making repairs in masonry, when new work is to be connected with old, the mortar of the old work must be entirely cleaned off along the surface where the junction is to be made, and the surface thoroughly wet. The bond and other construction details will depend upon circumstances. The surfaces connected should be fitted as accurately as practicable, so that by using but little mortar no disunion may take place from settling. As a rule, it is better that new work should butt against the old, either with a straight joint visible on the face, or let into a chase, sometimes called a "slip-joint", Fig. 151, so that the straight joint may not show; but if it is necessary to bond them together, the new work should be built in a quick-setting cement mortar, and each part of it allowed to set before being loaded. In pointing old masonry, all the decayed mortar must be completely raked out with a hooked iron point and the surfaces well wet before the fresh mortar is applied. The lining of old walls should be not less than 8 inches thick and should be anchored every 2 feet.

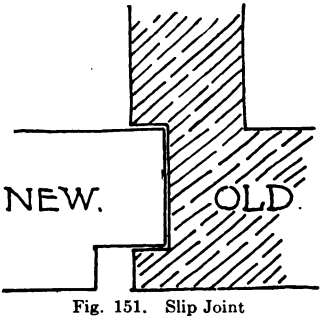


Fig. 151. Slip Joint

Brickwork for City Dwellings. The classification of city dwellings covers both those joined to each other in rows and, in outlying districts, those built as separate houses having each its surrounding grounds of greater or less size. The detached houses of the city stand between the typical country house and the grouped city mansions, and even though situated beyond the city limits where fire-resisting construction is required, it will usually pay to build them of masonry for the sake of durability as well as fitness,

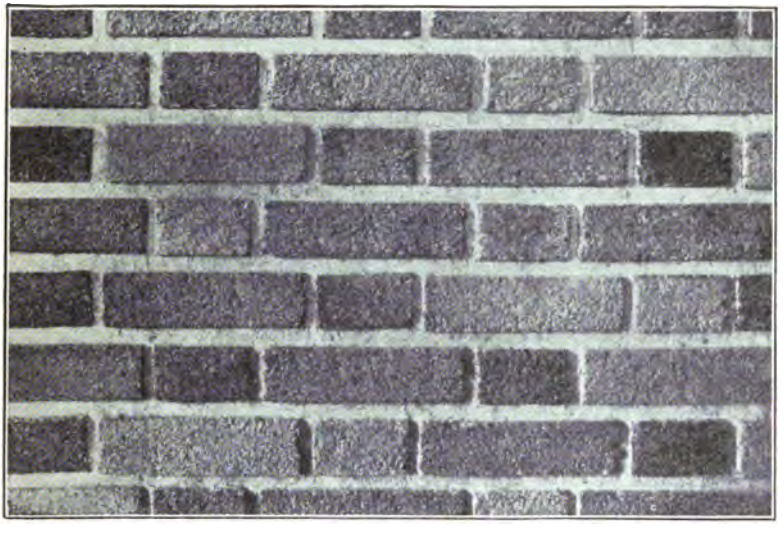


Fig. 152. Typical Wall of Tapestry Brick

and it is to brick, stone, or cement, that we turn for the exterior treatment outside as well as inside the city limits.

While common bricks as well as face bricks are suitable and customary for city dwellings, there has been developed a kind of brick particularly pleasing in texture and colors called "tapestry brick", as shown in Fig. 152. These are made in many shades of soft coloring; the bricks are extremely rough in texture, but when laid with heavy deep joints in a pleasing bond they give an excellent effect.

In using bricks for the exterior walls of a dwelling, it should be remembered that they do not make a wall which is wholly impervious to moisture; it is necessary, therefore, to take some precaution

to protect the inside plastering of the walls against dampness which might work through, however thick and well the wall may be built, and which would injure the tinting or papering, even though it did not loosen the plaster. This protection is commonly secured by furring the lathing off from the wall at least an inch, either by means of wooden strips or by a metal furring which comes attached to metal lathing for this purpose. Wooden strips are generally used, and when wooden laths are applied, the air space thus formed, running from bottom to top of each story, should be cut off at each floor at least, to prevent fire from spreading from story to story. In addition to this space it is well in many cases to apply a waterproofing compound to the back of the wall if the bricks are not very hard burned.

A better method of furring and one with greater fire resistance, consists in using thin terra cotta blocks secured to the back of the wall, to which the plastering may be directly applied. This does away with all wooden strips, except those necessary to provide nailings for the wood finish, and while more expensive, it is to be recommended for first-class work.

Supervision. In superintending brickwork, the main things to be observed have been pointed out in connection with the construction. Especial care should be taken to see that the bricks are properly wet, that sufficient mortar of the right quality is used, and that the joints are thoroughly filled. The bonding of the wall must be constantly noticed, especially that of facework and piers. The work should be measured from time to time and the position of all openings noted. Reveals and jambs should be measured and plumbed and the leveling of courses carefully observed. At the level of the floors the bedding of all bearing plates must be watched and the number and position of floor and wall anchors noticed. Recesses and flues should be carefully followed out, and the tying together of hollow walls must be frequent and effective. When work is stopped, the top of the wall should be covered, no matter in what season the work is being done—in summer to prevent rain from washing out the soft mortar, in winter to keep the water from entering and freezing. To obtain the best results, the laying of brick walls should not be attempted in freezing weather.

CUT STONEWORK

SELECTION OF STONE

First in consideration of the superintendence of stonework is the preparation of the material. In former times, for a work of importance, the stone was often brought to the building site in the rough, and all stone-cutting was done on the spot, but nowadays the stone is prepared at a stoneyard, often by machinery, and is ready to be set when received. The stone should be carefully examined *when delivered,* and not allowed to accumulate in great quantities without inspection, as a thorough examination is then more difficult. According to the nature of the work, the stone will have received more or less preparation by being worked into the various shapes and finishes suited for its purpose.

Varieties of Stone. The principal building stones in use in this country are granite, limestone, marble, and sandstone, and choice among these for a given building will be made with reference to color, durability, and strength. Probably the question of color will enter more into the selection than any other consideration, but this should not wholly overshadow the considerations of strength and durability. Cheapness and accessibility are highly important factors, and in cities resistance to atmospheric action and especially to fire, may well be taken into account. While no building stone will resist the action of fire for any length of time, of the different kinds of stone mentioned, fine-grained sandstone will probably withstand fire the best, granite next, and marble and limestone the least.

Testing Stone. Although it is possible in most cases to obtain stone for a building from some well-known quarry, the qualities of which have been sufficiently proved, occasion may arise when some simple test of a certain stone may be desirable. These tests should be made for compactness, absorption, strength, and fracture. The compactness of a stone can be best determined by comparison with some known stone of similar constituents, the less porous in appearance proving usually the more durable. The porosity may be determined by the power of absorption which the stone exerts. This may be found by immersing the thoroughly dried stone in water, and noting the difference in weight between the dry and the

wet stone. The absorption of 10 per cent of its weight denotes a degree of porosity which is likely to give the stone, after a time, a grimy appearance, while a hard nonabsorbent stone suffers little from age.

In situations where the atmosphere is charged with acids, as in large cities or manufacturing towns, there will be danger from the solubility of the stone, especially in damp climates. Too great a tendency to solubility may be discovered by soaking the stone in a dilute solution of acid, or by dropping acid upon the surface, when the presence of soluble carbonates will be denoted by an effervescence. The presence of substances easily soluble in water may be detected by placing some of the powdered stone in a glass with water and allowing the particles to settle. If the water is later disturbed, the presence of soluble matter will cause the water to turn muddy; if the water remains clear, the presence of only insoluble crystals is denoted.

FINISHING OF STONE

The method of finishing a stone has a great effect, not only upon its appearance, but upon its durability. The less pounding

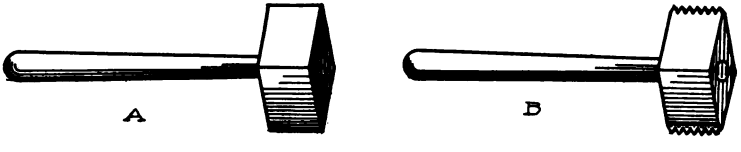


Fig. 153. Stone Axes. *A*—Solid Edge; *B*—Tooth Edge

a stone receives the stronger it will be, since the repeated jar tends to separate the particles and so to impair the durability of the stone. For this reason it is only granite and hard sandstones that are usually treated by hammering the surface, the softer stones being generally finished by the use of some form of chisel.

Tools. The principal tools used in stone-cutting are the following:

Axe or *peen hammer*—a solid tool with two cutting edges, used for making the draft line or margin on granite, and in leveling off the face, Fig. 153-*A*.

Tooth axe—similar to the axe, except that the cutting edges are divided into teeth. This is used on sandstones as well as on granite, Fig. 153-*B*.

Bush-hammer—a square head cut into a number of points and used for finishing sandstone and granite, Fig. 154-*A*.

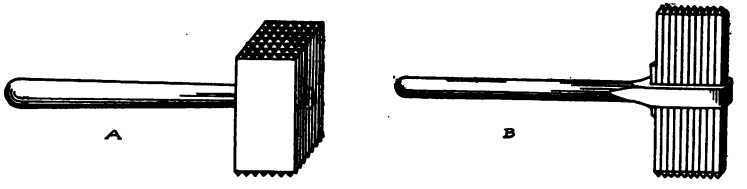


Fig. 154. *A*—Bush-Hammer for Finishing Stone and Granite; *B*—Crandall Used for Finishing Sandstone

Crandall—an iron handle with a long slot at one end into which are wedged a number of double-headed points. These points are secured by a key and may be removed for sharpening. This is a common way of finishing sandstone after the surface has been leveled by means of a tooth chisel, Fig. 154-*B*.

Patent hammer—this consists of a number of thin blades of steel which are bolted into a heavy head and is used for finishing granite and hard sandstones, Fig. 155-*a*.

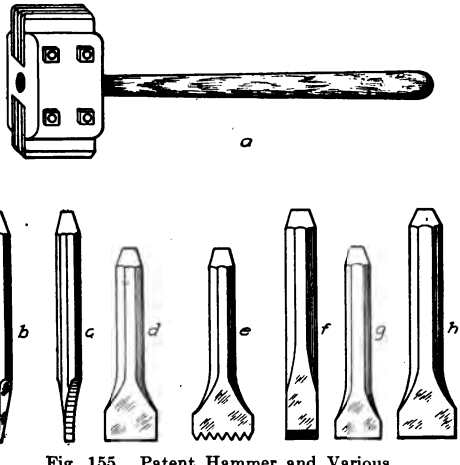


Fig. 155. Patent Hammer and Various Forms of Chisels

Chisels—various forms, among which are to be found the point *b*, Fig. 155, chisel and drove *c* and *d*, the tooth chisel *e*, all for use with a mallet; the hammer chisel *f*, and pitching tools *g* and *h*.

Finishes. The simplest of the various finishes which are given to cut stone is the *rock face*, shown in Fig. 156. In this, the face of the stone is left rough, the edges being pitched off to a line. A margin or draft line is often cut around the edge, leaving the center

with rock face, Fig. 157. *Pointed work*, Fig. 158, is done by taking off the surface of the stone with a point, and is made rough or fine

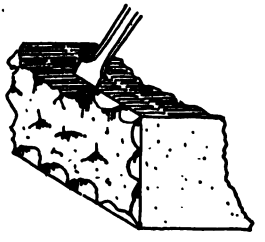


Fig. 156. Pitching Off for Rock Face

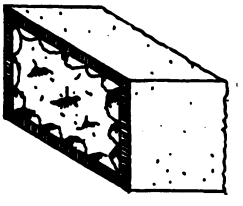


Fig. 157. Rock Face with Draft Line

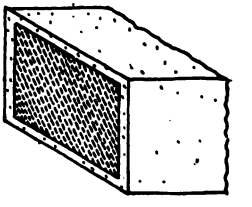


Fig. 158. Pointed Work

pointed according to the position or importance of the stone. This is used mainly for granite, a similar effect being obtained in soft stones by the use of the tooth chisel. *Tooled work*, Fig. 159, is done in straight lines clear across the face of the stone and is used a great deal for sandstone and limestone.

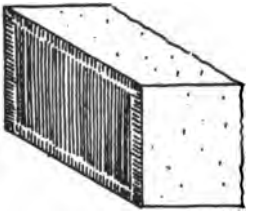


Fig. 159. Tooled Work

Bush-hammering, as its name implies, consists in hammering the stone, usually granite, with a bush-hammer, leaving the surface covered with points. *Patent hammered work*, Fig. 160, leaves the surface covered with a series of ridges. It is known as "six-cut", "eight-cut", or "ten-cut" work, according to the number of points to the inch. This is the customary finish for granite and generally eight-cut

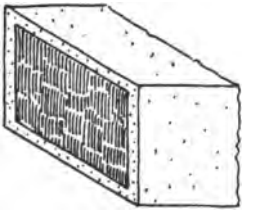


Fig. 160. Patent Hammered Work

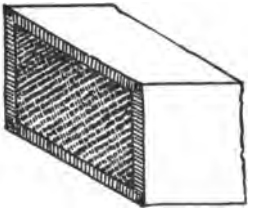


Fig. 161. Crandalled Work

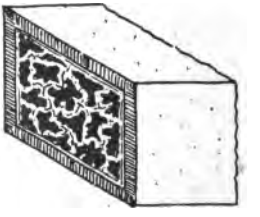


Fig. 162. Vermiculated Work

work is called for. *Crandalled work*, Fig. 161, is used for sandstone more than any other finish, and consists of a series of lines either crossing each other or running all one way, according to whether

the crandall is used from one side or from both. If a smooth finish is desired the stones may be rubbed. This is easily and cheaply done when the stone is first sawed, and makes a good finish. *Vermiculated work*, shown in Fig. 162, is obtained by working the whole surface over in imitation of the destruction by worms. This is expensive and is rarely used except for quoins.

Supervision. The inspection of stone at the building should be very thorough, especially in the matter of finish. The finer the degree of finish the more costly is the labor, and for this reason there is often a tendency to slight the work. Eight-cut granite will often be found to be six-cut, and fine pointed or fine crandalled work will sometimes be found to be rough and coarse.

STONE MASONRY

Rubble. Of the different kinds of stonework, rubble masonry requires the least preparation of the material. It is used for many sorts of construction, from ordinary foundation walls, such as we have already considered, to the handsome well-pointed masonry of churches and other buildings.

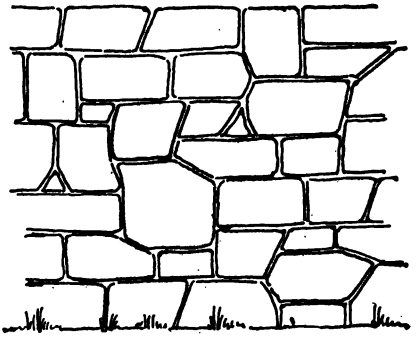


Fig. 163. Uncoursed Rubble

Types. Two definite classes of rubble work are recognized: (1) *uncoursed rubble*, in which stones of irregular shape are laid as they come to hand with no attempt at level courses, Fig. 163; and (2) *coursed rubble*, in which the blocks are leveled off at regular heights to a horizontal bed, Fig. 164. A wall of rubble is finished by pointing up the joints with cement mortar, colored as preferred, but usually matching the stone when that is at all even toned. Sometimes a false joint of red or white mortar is run upon this pointing to imitate ashlar work.

Uncoursed rubble in some cases is laid with the pieces having hammered joints which are fitted together with no spalls, or small stones, between, Fig. 165. This is an expensive and tedious process but is very effective when well done. The coursing of

rubble is not necessarily uniform, or at the same level throughout, but may rise and fall by level stages to accommodate the size of the materials.

Laying Stone. The superintendence of this class of work, beyond a general inspection of the quality and soundness of the

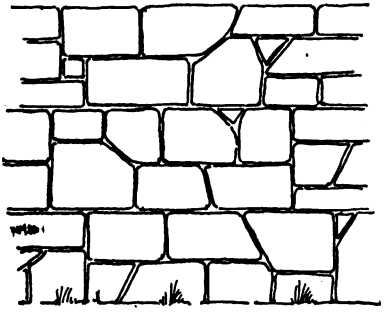


Fig. 164. Coursed Rubble

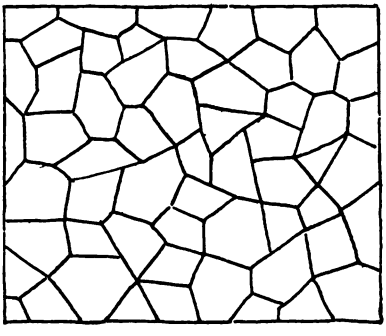


Fig. 165. Hammered Joints with no "Spalls"

stone, involves mainly seeing that the stones are well laid after they have been suitably prepared by roughly squaring them with a hammer, and knocking off all weak angles and projections. The stones should be clean and free from dust, and should be moistened before being laid. Mortar must be used in sufficient quantities to permit each stone to be firmly placed, and all hollows between the large stones should be filled with small stones carefully bedded in the mortar. The large stones should be laid on their natural bed, and should be so used that the side parallel to the bed will be the largest, so that the stones will lie flat and in no case be set on edge or on end. Care must be taken to break joints, and no side joint should form an angle with the bed of less than 60 degrees.

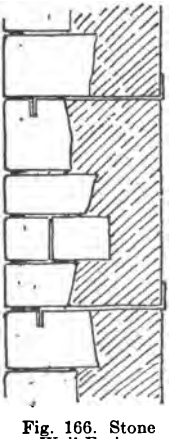


Fig. 166. Stone Wall Facing with Iron Ties

Bonding Stone. The bonding of a rubble wall must be carefully watched. Bond stones must be freely used. If the rubble is backed with brick, as is often the case, iron clamps and ties should be inserted, which may run through the wall and turn up behind the brick if the back of the wall is to be concealed, and which should run to the inside

course of bricks in any case, Fig. 166. If rubble is used as a backing for cut stone, the facing should contain a large proportion of thick stones which will bond well with the rubble. These bond stones may be left rough at the back and sides, but the upper and lower beds should be level, so that the stones will have no tendency to wedge off the backing. The backing should be carried up at the same time as the facework, with the coursing leveled off at the same place. A good proportion of thick stones running two-thirds or more across the thickness of the wall is better than a few extending through the wall.

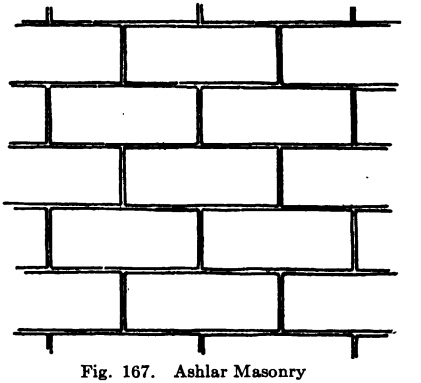


Fig. 167. Ashlar Masonry

Ashlar. Ashlar masonry consists of blocks of stone which have been cut to a regular figure, generally rectangular in shape, and laid in courses usually a foot or more in height, Fig. 167. If the courses are not maintained at the same level continuously, but are laid of stones of unequal height which are, however, still level and plumb, the work is called *broken ashlar*, Fig. 168.

In all ashlar work with soft material, such as limestone, no stone should have a length greater than three times its height. In harder stone the length may be four or five times the height. The thickness in soft stone may be once and one-half or twice the height; in hard stone, three times the height.

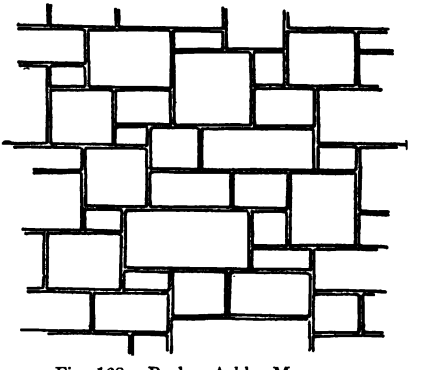


Fig. 168. Broken Ashlar Masonry

Laying Stone. The bed upon which the stones are laid should be level, cleared of dust or refuse, and well moistened with water. Upon this the mortar is spread evenly. Wooden wedges of the thickness of the joint are then laid on the face of the bed, and the stone carefully lowered upon them, to be moved into exact position

by the aid of a pinch bar. In using a bar or rollers to handle cut stone, it will be necessary to protect the edges of the stone by bagging or other "softening". When the stone is in its final position, the wedges may be removed and the stone settled into place and leveled by striking with a wooden mallet. In the case of heavy stones, where there would be danger of the weight of the stone squeezing the mortar out of the joint, the wooden wedges are allowed to remain until the mortar has set.

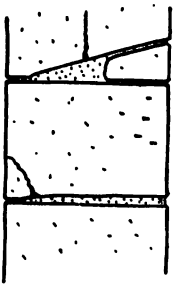


Fig. 169. Bad Effects of Hollow and Slack Joints

The bed of mortar should be kept back an inch or so from the face of the stone, so that the stone will not bear on its outer edge. This will save raking out the mortar when the wall is to be pointed, and will prevent any danger of the splitting-off of spalls on the face, which might occur on account of the mortar on the face of the joint becoming hard sooner than the inside, and the unequal settlement bringing pressure on the edge of the stone. The same mishap may occur if the bed of the stone is cut hollow or slack, as in Fig. 169, when the settlement of the mortar will bring the whole pressure upon the front edge of the stone. For this reason, care should be taken that the bed joints are square and true.

Door and window sills should be bedded only under their ends, as the natural settlement would cause them to break if bedded under the opening, Fig. 170. Stone work in damp situations should be set in cement mortar, but lime may be used if the situation is dry. Limestone and marble, and some sandstones, are often badly stained by the use of cement mortar, and inquiry in respect to this should always be made before using an unfamiliar stone. In case of danger of staining, Lafarge cement, made of lime, plaster of Paris, and marble dust, may be used; it should be plastered over the back of the stone as well, if cement must be used in the backing.

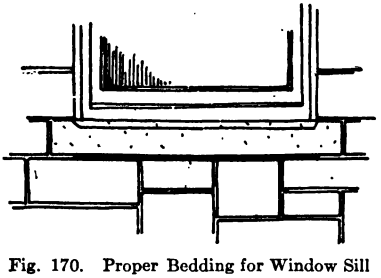


Fig. 170. Proper Bedding for Window Sill

Bonding Stone. Care must be taken that no vertical joint in

any course comes over a joint in the course below; the stones should break joints or overlap, preferably to an extent of from once to once and a half the height of the course, so that each stone will be supported by at least two stones of the course below, and will in its turn support at least two stones of the course above. This will not only distribute the pressure of the weight above, but will tie the wall together in its length by means of the friction of the stones where they overlap. The thickness of the stones should also vary so as to make a bond in and out of the wall, Fig. 171, and at least one stone in every ten square feet of wall should be the full thickness of the wall. The strongest bond in a wall of cut ashlar is one in which each course contains a header and stretcher alternately, the outer end of each header coming at the middle of the stretcher above and below, Fig. 172.

Fig. 171.
Bonding Stone

In broken ashlar work, the bond should be carefully preserved, and if there is a brick backing it will be convenient to use stones of a thickness of 4, 8, and 12 inches, alternating so that the bond may be obtained through and through without much cutting of the bricks. As the joints of the brick backing will necessarily be more numerous than the joints of the ashlar facing, the former should be made as thin as possible, and cement should be used to prevent their shrinkage. The backing should not be less than 8 inches thick. If the facing is in courses exceeding a foot in height, each large piece should be tied to the brick by iron clamps, placed about every three feet in the length of the wall and every two feet in the height. It will be of advantage in this class of work if the horizontal joints are not allowed to run to a great length. Changing the level of the courses every four or five feet will make a good looking wall. Broken ashlar is usually prepared at the building site, but it is a saving if the stones are cut to the required heights in the yard, only the end joints being cut at the building.

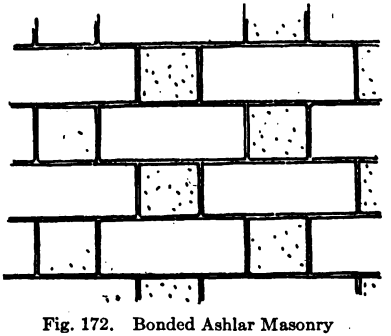


Fig. 172. Bonded Ashlar Masonry

Cast Stone. An increasing use is being made of cast stone or concrete stone, a manufactured product of a rather fine aggregate of crushed stone and Portland cement. This is molded in forms, machine or hand tooled, and may be cut to detail and set in the building in the same manner as natural quarried stone. A variety of effects of texture and color may be obtained by different aggregates and tooling. The natural quarried limestone, sandstone, or granites may be closely imitated, or the material itself may be given a special character by mechanical treatment, to vary the surface or expose the aggregate.

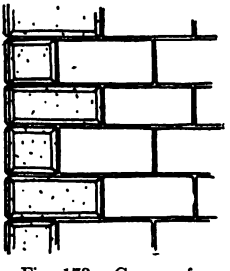


Fig. 173. Corner of Masonry Wall Showing Quoins

In the case of lintels or other members which support a tensile strain, steel rods or bars are added as reinforcement. The reinforcement permits the use of the cast stone for upright members when delicacy as well as strength is essential, as in shafts, pedestals, and other ornamental pieces, and it is used to a great extent for fountains, urns, reliefs, and sculptured or molded forms.

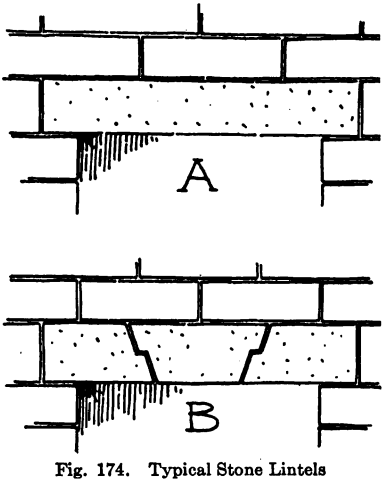


Fig. 174. Typical Stone Lintels

Quoins, Jambs, and Lintels. The corner stones of a building are called quoins and they are often given prominence over the face of the wall, Fig. 173. In broken ashlar the quoins should be of as great height as the largest of the wall stones. Stones at the sides of openings are called jambs and are often used in a manner similar to quoins.

Lintels or caps are the stones which cover door or window openings. They are usually in one piece, Fig. 174-*A*, but are sometimes necessarily jointed, Fig. 174-*B*. In the latter case the joints should be "toggled", as shown. If the lintel spans an opening which is too great for its carrying capacity, it may be assisted by the use of a steel angle bar or beam, Fig. 175. Lintels should bear at

the ends at least 4 inches, and if the lintel is thicker than the jamb, it should have bearing enough to reach beyond any recess which

Fig. 175. Section Showing Steel Support of Lintels

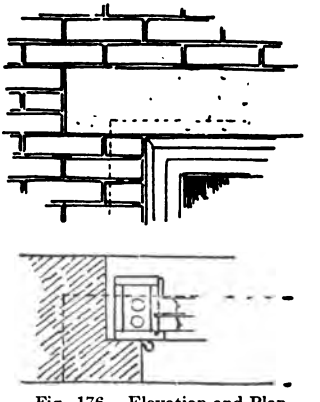


Fig. 176. Elevation and Plan Showing Bearing of Stone Lintels

the window frame may require, Fig. 176, so that the inside of the lintel will be supported.

Columns. Columns should be cut in one piece where the material will allow, with separate capitals and bases, and great care must be taken in cutting, and also in setting, to have the bed joints at right angles to the axis of the column. Clear cement mortar

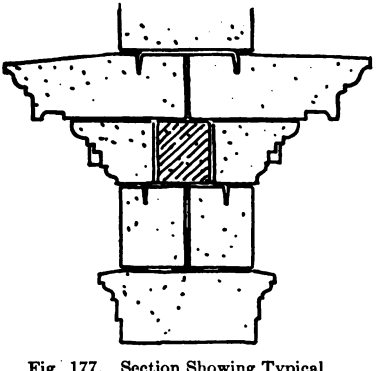


Fig. 177. Section Showing Typical Built-Up Cornice

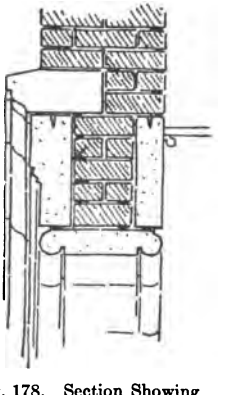


Fig. 178. Section Showing Arch Construction

should be used for setting, and, to prevent chipping the column, attention must be given to keeping the outside of the joint empty

for a depth of at least three-quarters of an inch. Lintels or cornices over columns are often exposed on both sides and should be cut from one stone, if practicable; if not, they may be built up as shown in Fig. 177, the stones being very carefully tied and clamped together.

Arches. Arches, if too large to be of solid stone, may be built up where both sides are to show, Fig. 178. In the setting of stone arches great care is necessary to preserve the perfect form of the arch. The joints should always be of equal thickness throughout and the mortar kept back from the face. This is of greater necessity than in the horizontal courses, as the joints of the arch are under increased pressure. The backing should be laid in cement, and well tied to the stones of the arch by clamps. Where two arches come together, the first stone, called the skewback, should be in one

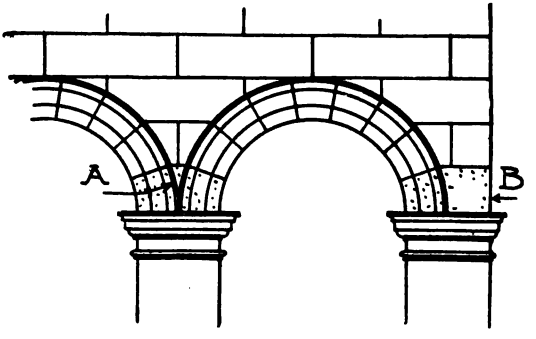


Fig. 179. Arches with Solid Skewbacks

piece for the two arches, Fig. 179, for if each stone were cut to the shape of its arch there would be left a small wedge-shaped stone, *A*, which might crowd the arch stones in. Where an arch comes near to a corner, as at *B*, the skewback and the corner stone should also be in one piece.

Flat arches are often used, but, while they are architecturally pleasing, they are liable to constructional weakness, and if they cannot be given a good height, they should be cut as a lintel with false joints on the face. If the opening is not wide, a flat arch may be cut in three pieces, the key with its side pieces being separate from the other two pieces, Fig. 180. In this case, and also in the case of *B* in Fig. 174, the center should be set about one quarter-inch higher than the jambs, to allow for settlement.

Centering of Arches. For the construction of arches, whether of stone or other material, wood centers are required. These should be strongly made and left in position until the mortar in the joints has become hard. Centers for small arches are usually made of plank, with two ribs set apart to the thickness required, and connected for a bearing surface by strips of $\frac{7}{8}$-×2-inch stick nailed to the tops of the ribs. A center of this sort is supported by wooden posts from the sill or floor below. If the arch is of a large span, the number of pieces must be greater, in order to use planks of ordinary width, and the center will need additional support and ties, as shown by Fig. 181. These centers should be wedged up in setting, to allow easy adjustment or removal.

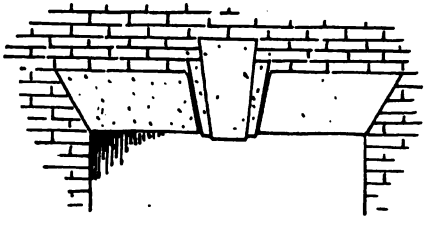


Fig. 180. Flat Arch of Stone

General Rules for Laying Stone. The following rules for the laying of stone are, in general, applicable to all work:

1. Build the masonry, as far as possible, in a series of courses, perpendicular, or as nearly so as they can be made, to the direction of the pressure which the stones must bear, and by breaking joints, avoid all long continuous joints parallel to that pressure.

2. Use the largest stones for the foundation course.

3. Set all stones which consist of layers in such a manner that the principal pressure which they have to bear shall act in a direction perpendicular, or as nearly so as possible, to the direction of the layers. This is called "laying the stone on its natural bed", and is of primary importance for strength and durability.

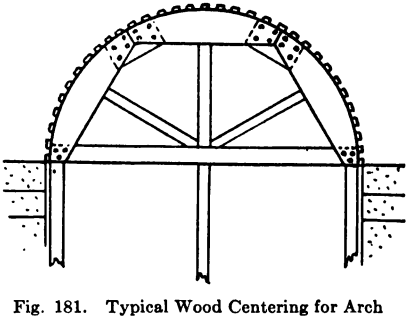


Fig. 181. Typical Wood Centering for Arch

4. Moisten the surface of dry and porous stones before bedding them, in order that the mortar may not be dried too fast and reduced to powder by the stone absorbing its moisture.

5. Fill every part of every joint, and all spaces between the stones, with mortar, taking care at the same time that such spaces shall be as small as possible.

6. The rougher the stones, the better the mortar should be. The principal object of the mortar is to equalize the pressure, and the more nearly the stones are dressed to closely fitting surfaces, the less important is the mortar. Not infrequently this rule is exactly reversed, i.e., the finer the dressing, the better the quality of the mortar used.

7. All projecting courses, such as sills and lintels, should be covered as the work progresses with boards, bagging, etc., to protect them from injury and mortar stains. When setting cut stone, a pailful of clean water should be kept at hand, and when any fresh mortar comes in contact with the face of the work it should be immediately washed off.

Pointing. When the exterior masonry of the building is completed, the whole of the stonework must be washed down and pointed. This should never be done in freezing weather, and if done in extremely hot weather there will be danger of the mortar drying too quickly. For ordinary stonework, Portland cement combined with an equal quantity of sand and enough water to make a stiff mixture, makes a good pointing mortar; but for limestone, marble, or any stone which would be stained by cement, lime mortar, Lafarge, or other non-staining cement must be used. If the joints are not already clean, they must be raked out to the depth of an inch and moistened, and the pointing mortar applied with a small pointing trowel and then rubbed in smooth with a jointing tool. Either a concave, flush, or projecting joint may be made, but the concave joint is more durable than the others. The washing-down of the stonework will be done at the same time as the pointing, and this should be done similarly to the finishing of brickwork, with dilute muriatic acid applied with a stiff scrubbing brush. Wire brushes are sometimes used to clean down marble and granite work.

Pointing is in some localities made a distinct branch of the building trade, and in others it is part of the mason's work. When possible, a professional pointer should be obtained, as he will usually have better appliances, ready for immediate use, than will the mason, whose use for them will naturally be occasional.

Supervision. The superintendence of cut stonework means constant attention, as it is expensive and annoying to be obliged to remove a stone after it has been set in the wall. There are, moreover, many devices by which defective stock and workmanship can be concealed, and these can be detected only by diligence and the exercise of considerable knowledge of practices.

The first thing necessary is a thorough inspection of the stone as delivered, and a careful search for defects which the superintendent knows are likely to occur in the various kinds of stone. Granite often develops local defects, such as seams, knots, or brown stains, known as sap. Stains will be apparent upon examination, but seams are to be detected by striking the stone with a hammer, when a flawless stone will ring clearly.

Sandstones are often found with small holes, called sand holes, and may be of an uneven color; there may also be local discolorations, which are sometimes developed by cutting and do not appear until so much expense has been put upon the stone that the contractor is often tempted to pass it as perfect if he can do so. Considerable firmness may be necessary to obtain work in exact conformity with the specifications, but this should be insisted upon at all times. Another defect which requires the exercise of great judgment is the matter of patched stones. Expensive stones are often marred by the cutting or handling, and are then so skilfully patched by the use of melted shellac and stone dust, that they may be overlooked until set, when they often cannot be replaced without considerable delay. In this case, if the owner agrees, they may be allowed to remain, but the superintendent should make sure that the patching is properly done. If a molding has been knocked off and simply stuck on again with shellac, the superintendent should insist that a square block be dovetailed in and the molding re-cut.

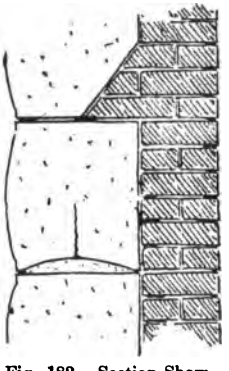


Fig. 182. Section Showing Improper Stone Cutting

In the dressing of the stone, care should be taken to see that the work is as finely cut as called for, and that the moldings are cut according to details and perfectly matched. Ashlar work should be cut with full bed joints without hollows or thin edges, Fig. 182,

and so as to lie on its natural bed. Anchors should be freely used, and the bonding of ashlar and backing carefully watched. The setting of columns, arch stones, and molded work should be especially noted to see that the mortar is kept well back from the edges to prevent the stones from splitting off, and the tying of continuous courses to each other at the ends should be insisted upon. Projecting courses must be beveled off on the top to shed water and should also have a drip cut on the under side, so that the water will drop off and not run down the side of the building, Fig. 183. The bed which lies in the wall, however, must not be beveled, but must be cut level to maintain the full bearing of the stones in the wall.

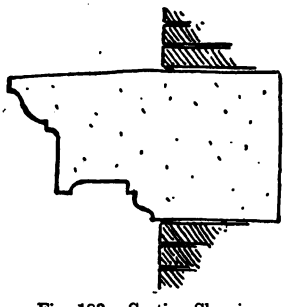


Fig. 183. Section Showing Drip of Cornice Stone

ROOFING WORK

After the completion of the exterior masonry of a building comes in most cases the covering-in, since practically nothing more than the rough work of flooring can be done inside until the work is protected from the weather by a roof. For the roof covering, a variety of materials may be used, common among which may be mentioned tin, copper, slate, tiles, asbestos shingles, and, for flat roofs, tar and gravel composition. There are besides many patented preparations of paper and tar suitable for temporary roofs.

Tin Roofs. The cheapest, and at the same time the least satisfactory of permanent roofing materials is probably tin. This

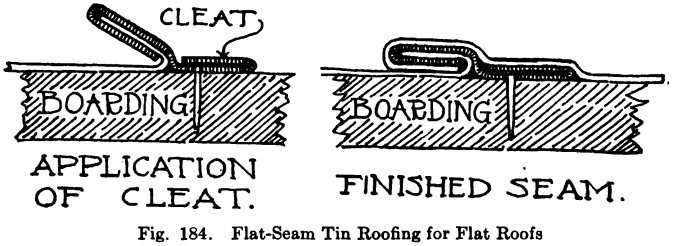


Fig. 184. Flat-Seam Tin Roofing for Flat Roofs

may be used on steep roofs or on comparatively flat roofs, the least inclination advisable being $\frac{5}{8}$ inch to the foot.

Method of Laying. The boarding under a tin roof should be smoothly matched and covered with dry sheathing paper, and any holes in the boarding should be filled up. The sheets of tin for a flat roof are prepared by turning the edges over so as to lock with the edge of the next sheet, Fig. 184, and they should be painted on the underside and allowed to dry before being laid. The usual method is to run the sheets in courses across the roof, each course being nailed at the top with short wire nails under the lap of the tin. This method of fastening should not be permitted in a roof of any extent, as the rigid nailing of each sheet will give the roof a wavy appearance when the metal expands, and the wrenching of the tin will often draw out the nails or tear the tin from the heads. If this occurs, the great mass of tin will rattle against the roof, and

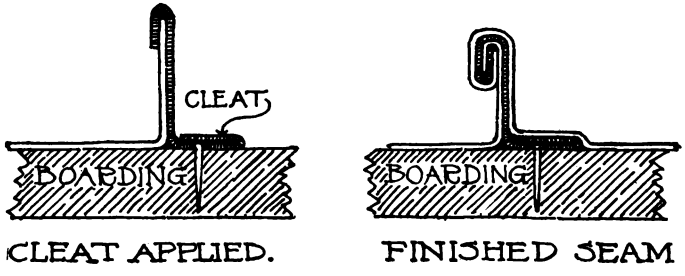


Fig. 185. Standing-Seam Tin Roofing for Large and Steep Roofs

will be, besides, liable to leak. The proper way to secure the tin is by the use of strips of tin called cleats, cut about $1\frac{1}{2}\times 4$ inches. These cleats should be locked over the turned edge of the sheet and nailed to the roof, being concealed by the next sheet added; they should be used about every 14 inches along the upper edge and the side of the sheet of tin. This method of laying tin allows the metal to expand without drawing the nails or destroying the tin. When the roof has been covered, the seams are all pounded down and carefully soldered, making a continuous covering.

Against chimneys, dormers, or other openings in the roof, the tin should be turned up at least 4 inches to be capped by vertical flashings of lead or zinc, with gable ends carried out and tacked over the edge of the moldings and finish. Connections should be made with metal gutters and finish by locking and soldering.

For large and steep roofs of tin, greater allowance must be made for the expansion, and this is done by means of standing seams, Fig. 185, which are formed by locking together vertically the sloping seams of the tin, the horizontal seams being flat. To do this the sheets of tin are locked and soldered together into strips running up the roof, and these strips are turned up and locked together without soldering, being held in place by cleats. When finished, the seam should be about an inch in height. Standing seams are often used for effect, and a still stronger appearance may be given by ribs of wood over which the tin is locked.

Quality of Tin. The tinning of a roof should be carefully watched to see that tin of the required quality is used, that the cleats are put in as described, and that acid is not used in soldering. Only resin should be allowed as a flux for soldering, as acid, which is more easily used, injures the tin. The standard sizes of roofing plates are 14×20 inches and 20×28 inches; and they are made in two thicknesses marked IC and IX, the former weighing 8 ounces to the square foot and the latter 10 ounces. The lighter brand is more extensively used, but for first-class work and flashings, nothing but IX tin should be permitted. Imperfect sheets, called "wasters", are put upon the market, and are packed in boxes marked ICW or IXW according to the thickness, so that when perfect plates, called "prime", are called for, the superintendent should reject any boxes marked W. The best grades of tin are now sold with the name of the brand and the weight stamped on every sheet, and this should be noted for first-class work. It is worth remembering that the smaller sheets will make a stronger and better roof than the larger, and for a steep roof with standing seams the sheets should be laid with the width between the sloping seams, as this gives more chance for expansion. All traces of resin should be removed, and the roofs should not be painted until the rain has had a chance to wash the tin clean of grease.

Supervision. Tin roofs, while under construction, should be kept clean, and rubbish never allowed to collect, as nails and other hard substances are likely to cause perforations in the roofing if stepped on by careless workmen. If tin is used for fireproofing a roof, the top filling should be of porous terra cotta to receive the nails, and an even surface secured by smoothly plastering the surface of the

terra cotta with hard cement. Steep roofs are often made fireproof by using hollow terra cotta tiles between T-irons, which may be treated in the same way.

Standard Practice. The National Association of Sheet Metal Contractors has made the following recommendations as a guide for standard practice:

Tin-Roofing Specifications

Tin Roofing Work. All tin used on this building shall be ——— brand. No substitute for this brand will be allowed. Use IC thickness for the roof proper, decks, etc., and IX thickness for valleys, gutters, and spouts, as required by design. One coat of red lead, iron oxide, metallic brown, or Venetian red paint, with pure linseed oil, shall be applied to the underside of the tin before laying.

For Flat Seam Roofing. Edges of sheets to be turned one-half inch; all seams to be locked together and well soaked with solder. Sheets to be fastened to the sheathing boards by cleats spaced eight inches apart, cleats locked into the seams and fastened to the roof with two one-inch barbed wire nails; no nails to be driven through the sheets.

For Standing Seam Roofing. Sheets to be put together in long lengths in the shop; cross-seams to be locked together and well soaked with solder; sheets to be made up the narrow way in the rolls and fastened to the sheathing boards by cleats spaced one foot apart.

Valleys and Gutters. To be formed with flat seams well soldered, sheets to be laid the narrow way.

Flashings. To be let into the joints of the brick or stone work, and cemented. If counter-flashings are used, the lower edge of the counterpart shall be kept at least three inches above the roof.

Solder. To be of the best grade, bearing the manufacturer's name, and guaranteed one-half tin and one-half lead—new metals. Use only resin as a flux.

Caution. No unnecessary walking over the tin roof or using same for storage of material shall be allowed. In walking on the tin, care must be taken not to damage the paint nor break the coating of the tin. Rubber-soled shoes or overshoes should be worn by the men on the roof.

Painting Tin Work. All painting of the tin work to be done by the roofer, using red lead, iron oxide, metallic brown, or Venetian red paint, with pure linseed oil—no patent dryer or turpentine to be used.

All paints to be applied with a hand brush and well rubbed on. Tin to be painted immediately after laying. A second coat shall be applied in a similar manner two weeks later.

No deviation from these specifications shall be made unless authority is given in writing by the architect. Only a first-class roof will be accepted.

Copper Roofing. The methods of laying copper roofing differ very little from those described for tin, except that the sheets of copper are much larger and therefore lend themselves more easily

to molded forms, such as ridge rolls, hips, finials, etc. Copper roofing is often "crimped", that is, the surface is covered by fine corrugations, which give a softer and more even appearance than the plain metal, and conceal the waviness which plain sheets may show.

Slate Roofing. On roofs which pitch more than 5 inches to the foot, slates may be used. With a slate roofing the boarding should be matched and covered with tarred paper. On this surface the slates are laid in layers, beginning at the eaves with a double course and working upward to the ridge. The gaging of the courses is determined by the head cover, that is, the distance which the top of the slate is overlapped by the second slate above, Fig. 186. This lap should not be less than 3 inches.

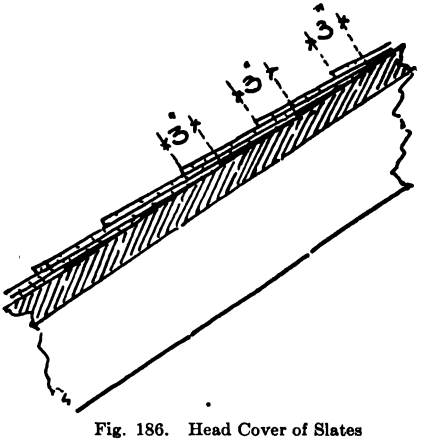


Fig. 186. Head Cover of Slates

Slates are usually 8×16 inches and 10×20 inches in size, and run from about $\frac{3}{16}$ to $\frac{1}{4}$ inch in thickness. They should be put on with tinned, galvanized, or copper nails, two to each slate, and care must be taken that the nails are driven in, not hard enough to crack the slates, and yet hard enough to prevent them from rattling. The nails should have large heads and be 3-penny or 4-penny nails. Where slates are cut, as against hips or valleys, care should be taken that each slate receives two nails. For thick slates the holes should be drilled and countersunk. First-class work requires that the slates, for a distance of 2 feet each side of valleys and above gutters, should be "rendered", that is, bedded in elastic cement, and the same precaution should be taken for the width of a foot at hips, ridges, and all vertical parts. If slating is to be used on roofs of very slight slope, the whole should be laid in cement.

Slate Roofing on Flat Roofs. Flat composition roofs are often surfaced with slate in place of the final coat of gravel or slag, the process up to this point being the same as if a gravel finish were to be used. This produces a roof which may be freely walked upon

and permits the removal of snow without injury, whereas a gravel coating is a protection mainly against the elements, and is not suitable for use unless further protected.

Flashings. Valleys in slate roofs should be open valleys of metal at least 18 inches wide, often laid, like a tin roof, with the end joints locked and soldered and the edges securely nailed to the roof boarding. Tin, zinc, or copper may be used, but copper is to be preferred for valleys, as well as for all flashings. Where the slope of the roof changes or where dormers, chimneys, or other vertical parts cut the roof, wide aprons of metal should be set and turned up against the rising wall to be covered over by the wall covering, or by lead counter-flashings built into the brickwork. Gables are finished by continuous metal members, run at least 8 inches under the slates and tacked over the edge of the wooden finish, or cemented into grooves cut in stone copings, called reglets.

Raggle Blocks. Special blocks made of terra cotta or hard clay and having a reglet cast in the back may be obtained for use at the roof level if it is not desired to flash the back of the wall, or for use as a coping in case the wall is to be covered, Fig. 187. The blocks are made to receive the roof composition, or metal cap flashings, as may be desired. This style of construction is a great convenience where flashings have to be removed.

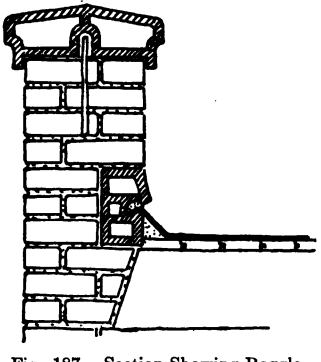


Fig. 187. Section Showing Raggle Block for Holding Roof Composition or Metal Flashings

A good practice is to cap all flashings; that is, the metal which runs under the slates is turned up against the wall, and a separate piece of metal is wedged and cemented into the reglet and turned down over the other flashing to within half an inch of the roof. This method allows free movement to each piece of metal, which is necessary because of expansion and shrinkage. For the same reason it is much better to form the valleys and hips of sheets which are laid in with each course, lapped, and not locked and soldered.

Various Methods of Laying. Slates are sometimes laid on strips of wood or battens without boarding, but this does not make so tight a roof. For fireproof roofs, however, it has been common to

secure the slates to small T-bars by bolts and then to plaster the underside, but a better way is to lay porous terra cotta blocks between the irons, to which the slates may be nailed or cemented. A method of slating which may be employed where absolute tightness is not required is one called half-slating, and consists in leaving between the sloping edges of each slate a space not exceeding half the width of the slate, Fig. 188.

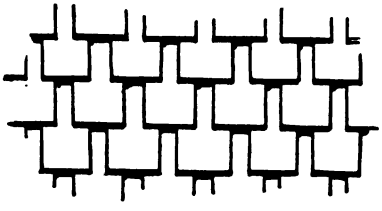


Fig. 188. Half-Slating Roof Covering

Qualities of Slate. In appearance, good slates should be of an even color without spots, and present a hard, straight grain, which should shine in certain lights with metallic, silken luster. They should be square and true, and free from warped or nicked edges, and neither too brittle nor too soft.

Tiles. Tiles for roofing, although by no means a modern invention, have of late years come into more general use in this country. They are made in a variety of shapes, the general principle in all cases being that of a slab of baked clay, molded with an interlocking roll or rim. Tiles are laid on battens or on boarding, as described for slates, but instead of a double lap for tightness, the tightness of this roof depends upon the fitting of the tiles into each other. Some of the modern forms of tiles are shown in Fig. 189. With tiles should be used copper or zinc for valleys and flashings, but ridges and hips are generally formed by tiles of special patterns. Plain tiles have long been used in England and in most cases have been found after years of service to be in as good condition as when new. Tiles may be used on roofs which have a pitch of more than $22\frac{1}{2}$ degrees, but they need a free use of elastic cement, especially in valleys, hips, and ridges. In appearance, tiles should be of even color, free from fire checks but well-burned and nonabsorbent, of uniform size, and without blisters, cracks, or warped surfaces.

Fig. 189. Standard Shapes of Roof Tiling

Cement Tiles. A variety of roofing tiles is made of Portland cement reinforced with metal. These are molded in large sizes, approximately 2×4 feet, and when laid on steel ribs they present

a surface on the underside which requires no further finish, and is suitable for warehouses, machine shops, and power houses where the roof has a reasonable pitch—usually not less than one-fifth of the whole span.

For flat roofs which are to be used for observation or roof-garden purposes, there is a kind of hard tile called "promenade" tile, or quarry tile, which is laid in cement as a paving, and has been used with good results. These tiles, usually from 6×6 inches up to 12×12 inches if square, or in equivalent oblong shapes, should be hard burned and sound and solid in every particular. When well laid in Portland cement they form a pleasing and permanent roof.

Asbestos Shingles. As a substitute for wood shingles, there are shingles made by molding asbestos fibers and Portland cement into a solid sheet under hydraulic or other extreme pressure. These shingles come in various shapes and colors, and are usually $\frac{1}{8}$ inch or $\frac{1}{4}$ inch thick; the latter are made with rough edges to resemble tiles or slate, but they are much lighter and tougher, allowing a lighter roof construction. The $\frac{1}{8}$-inch shingles are less pleasing than the thicker ones as they present a surface extremely smooth and uniform in appearance; they are made in patterns which run to diagonal as well as horizontal lines on the roof.

Selection having been made, the laying does not differ from the familiar construction of slate or tile covering, equal care being necessary to see that proper metal flashings are introduced in the portions especially exposed to rain or snow.

Composition Roofing. For roofs of a pitch of $\frac{3}{4}$ inch to the foot or less, a composition roofing, made of several thicknesses of paper coated with tar and covered with gravel on top, may be used to advantage. The mode of constructing a composition roof over wood consists, first, in covering the boarding with dry resin-sized felt with a lap of 2 inches, tacked only often enough to hold it in place. Over this are laid two full thicknesses of tarred felt, each sheet lapping two-thirds of its width over the preceding one, and the whole covered with a uniform coat of pitch mopped on. Upon this coating three layers of tarred felt are tacked, each lapped about 22 inches, and the whole mopped over and a thick coat of pitch flowed on. As the durability of the roof depends upon the paper,

only the best should be used, and the pitch should not be so hot that it will destroy the life of the paper. Upon the final coat of pitch is spread immediately, as a protection, a coat of clean, white gravel, completely covering the whole, Fig. 190.

In the case of a composition roof laid over a concrete surface, the operations are the same except for the first mopping of pitch

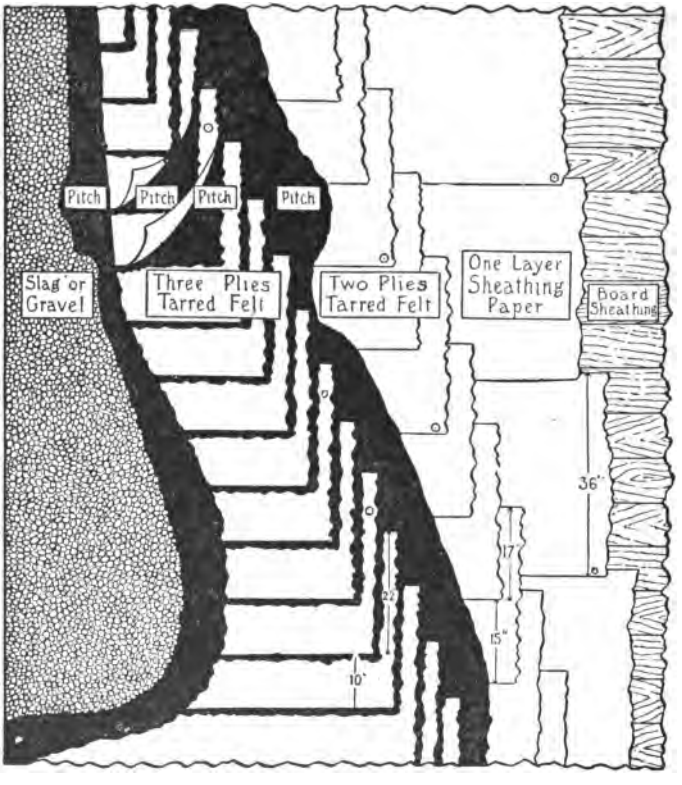


Fig. 190. Section Showing Layers of Composition Roofing on Board Sheeting
Courtesy of Barrett Manufacturing Company, New York City

directly upon the concrete, and the omission of the nailings which are required on a wooden roof, their place being taken by moppings of pitch.

This composition of tar and gravel makes a very good roof, but it is suitable only for roofs with a grade up to $\frac{3}{4}$ inch to the foot. If the roof is much steeper, the heavy coats of pitch will run in hot weather and, settling down, will gradually fill the gutters. A com-

position of pulverized slate and asphalt, applied in layers with felting, has been placed upon the market, and is more adaptable to various roof angles than tar and gravel.

The same precautions regarding the flashing of vulnerable parts that we have noted for slates or tiles, are needed in the laying of composition roofs, except in the case of the *plastic-slate* roofing; here the composition itself is of such a nature that it may be applied with a trowel directly to the walls or copings against which the finish is made; and since it is both elastic and adhesive, no great amount of metal flashing is needed.

Specifications for the Application of Pitch and Felt Built-Up Roofing with Gravel or Slag Surface

Incline. This specification should not be used where roof incline exceeds three (3) inches to one (1) foot.

Standard Specifications for Use over Board Sheathing

Roofing. *First*, lay one (1) thickness of Sheathing Paper or Unsaturated Felt weighing not less than five (5) pounds per one hundred (100) square feet, lapping the sheets at least one (1) inch.

Second. Over the entire surface lap two (2) plies of Specification Tarred Felt, lapping each sheet seventeen (17) inches over preceding one, and nail as often as is necessary to hold in place until remaining felt is laid.

Third. Coat the entire surface uniformly with Specification Pitch.

Fourth. Over the entire surface lay three (3) plies of Specification Tarred Felt, lapping each sheet twenty-two (22) inches over preceding one, mopping with Specification Pitch the full twenty-two (22) inches on each sheet, so that in no place shall felt touch felt. Such nailing as is necessary shall be done so that all nails will be covered by not less than two (2) plies of felt.

Fifth. Spread over the entire surface a uniform coating of Specification Pitch, into which, while hot, imbed not less than four hundred (400) pounds of gravel or three hundred (300) pounds of slag to each one hundred (100) square feet. The gravel or slag shall be from one-quarter ($\frac{1}{4}$) to five-eighths ($\frac{5}{8}$) inch in size, dry and free from dirt.

Flashings. Flashings shall be constructed as shown in detail drawings.

Inspection. The roof may be inspected before the gravel or slag is applied by cutting a slit not less than three (3) feet long at right angles to the way the felt is laid.

Supervision of Roofing Work. The supervision of roofing work of all kinds deserves the closest attention. Nothing is more unsatisfactory than to find leaks in the roof of a new building, and the time spent in securing a first-class job will be well spent. Slates and tiles are easily broken, and unless discovered and brought to notice at once, the broken ones will probably be overlooked by the con-

tractor. Composition roofs are easily slighted, and when finished give little indication of defects; the only practical way of determining that felt and pitch have been applied as specified is to cut a slit into the roof "not less than three feet long at right angles to the way the felt is laid", before the gravel or slag is applied. The cut can be repaired by laying five thicknesses of felt over it, and the spot will then be as strong as any part of the roof.

METAL WORK

Gutters. The best material for metal conductors is copper, but galvanized iron and tin are used to some extent. The usual type of copper gutter is shown in Fig. 191, but it is often necessary

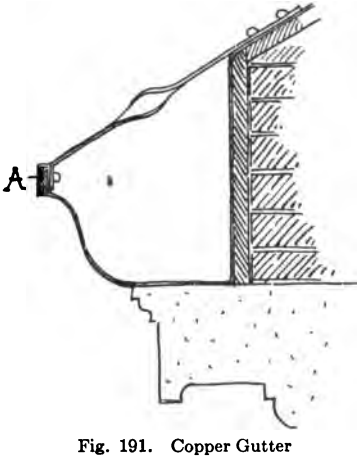


Fig. 191. Copper Gutter

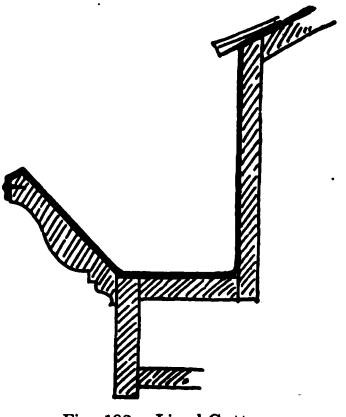


Fig. 192. Lined Gutter

that the face should be made of moldings to match or form part of a stone or wooden cornice. In such a case, the gutter is formed behind the finished molding, Fig. 192. The gutter shown in Fig. 191 is made of sheet copper, turned over an iron bar *A;* it is molded to form the trough, and made wide enough to run well up on the roof boarding, under the slates or other covering. Bars of copper or galvanized iron are bolted to the outer bar, and nailed and soldered to the roof. These bars should be given a short twist, as shown, so that the wash of the roof will drip off into the gutter, and not follow the strap down and soil the face of the gutter. In the case of the lined gutter, Fig. 192, the outer edge of the metal is tacked to the wood or tucked under an iron bar previously secured.

Standing gutters, Fig. 193, are sometimes used, where they will not be objectionable by reason of holding back the snow, but they are often a source of trouble.

In a great many cases of city building, especially of buildings

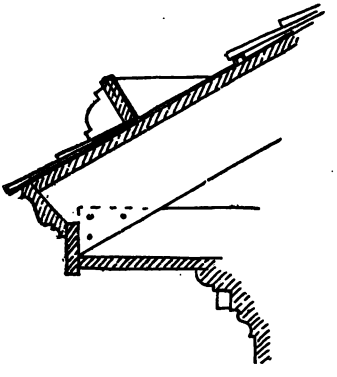


Fig. 193. Standing Gutter on Roof

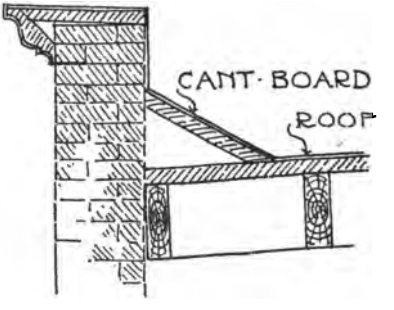


Fig. 194. Cant Board behind Parapet

with flat roofs, it is necessary or convenient to have the outer walls carried up as a parapet, and the roof water taken care of inside of the building. In this case a cant board is used, Fig. 194. This consists of a board surface set in the angle of roof and wall, and graded to the desired outlets, where conductors are placed inside of the wall.

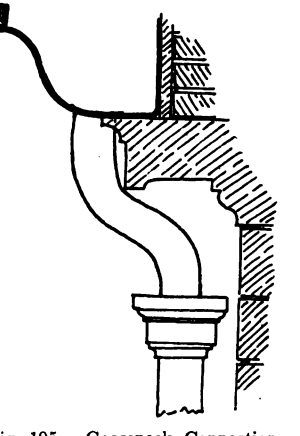


Fig. 195. Gooseneck Connection between Conductor Pipe and Gutter

Conductors. In the case of the inside conductors referred to, cast-iron soil pipes may be used; and if these are carried down in a brick wall, they should, if possible, be run in interior walls, with not less than 8 inches of wall between them and the outside air. The recess is often packed with some nonconducting material. Outside metal conductors are made of tin, zinc, galvanized iron, or copper, the latter being the most desirable and also the most expensive. Metal conductors should be made in some form which will permit expansion in case their contents are frozen solid. A corrugated round pipe or an octagonal or square pipe is to be pre-

ferred. Conductors are usually given ornamental tops of large or small proportions according to situation.

The connection between the conductor and the gutter is generally made by a bent piece of pipe, sometimes a continuation of the conductor, but often a separate piece of lead pipe, shown in Fig. 195, called a gooseneck. The opening from the gutter to the conductor should be protected by a strainer to prevent leaves, chips, or other substances from choking up the pipe, and the lower end, if connected with a drain, should be properly trapped.

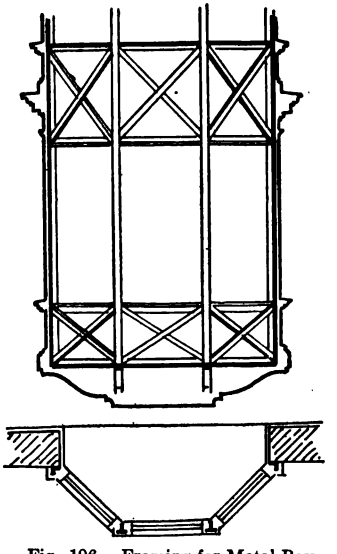


Fig. 196. Framing for Metal Bay Window

Supervision. The superintendence of gutters and conductors should cover the construction of the trough, if of wood to be lined, to see that it pitches in the right direction and to the required points. The weight of the metal should be examined, and the manner of securing both gutters and conductors carefully noted. Tin or iron surfaces which are concealed should be well painted, and all soldering faithfully done. The ends and backs of metal gutters must be examined to see that there is a sufficient width of metal to turn up against the wall, or to lie up on the roof, 8 to 10 inches being as little as it is safe to allow. All rubbish in the gutters must be removed, and all connections left tight and free from obstructions.

Galvanized Iron Work. The use of galvanized iron for exterior molded work and bay windows has of late years become an important factor in building construction. Especially is this true of modern fireproof buildings where it is desired to avoid the use of wood in the exterior finish. Belts, cornices, pilasters, door and window finish, and, in fact, all the trimmings of a building, which in former times would have been made of stone or wood, are now, to a great extent, made of galvanized iron or, if not too costly, of copper. The structural treatment of galvanized iron and copper being about

the same, it is necessary for us to treat only of the former, remembering that for large surfaces galvanized iron is the stouter material.

Bay Windows. Perhaps the greatest use of galvanized iron at present is found in building bay windows. Since in this construction the essentials are lightness and strength, it is usual to erect a light framework of steel, upon which the metal finish is secured, Fig. 196.

Cornices. Cornices are run on steel or iron brackets secured to the brick wall or the steel frame, whichever is more available. These brackets are shaped to conform roughly to the outline of the cornice, and it is allowable to insert a reasonable amount of boarding to form a base for any broad washes of metal, as boarding thus placed, outside of the walls and completely encased by metal, is not in any danger from fire. For heavy projecting cornices, the brackets should be made of steel angle irons securely built into the wall, or bolted to it or to the steel skeleton.

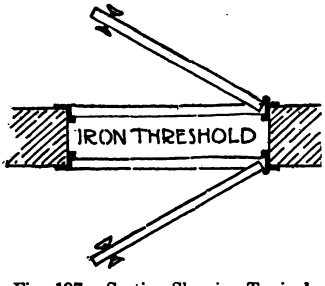


Fig. 197. Section Showing Typical Fire Doors

Tinned Doors and Shutters. Doors covered with tin are frequently used for the fire protection of exposed windows and other openings. Many city laws and insurance rules require that all windows within thirty feet of a source of danger from fire shall have metal-covered shutters of some kind. A wooden shutter completely encased in tin has been found to be an effective protection. For guarding openings in party or division walls, the same kind of doors are used, one on each side of the wall, leaving an air space between of about the thickness of the wall, Fig. 197. The laws generally require that these doors shall be set in rebated frames, and hung by various automatic devices of weights and fusible members, so that they will close at once if attacked by fire.

The best type of construction has a frame made of pine $1\frac{3}{4}$ inches in thickness with flush panels, covered with tin tacked on as described for roofing; shutters and small doors, however, are built of two thicknesses of $\frac{7}{8}$-inch pine, nailed together and crossing each other. As much care is necessary to preserve a tight interior for outdoor shutters as for a roof, as a small leak will soon rot out

the pine core. The joints are all made by locking and tacking the tin; soldering is prohibited, since the heat of a fire would melt it at once.

Skylights. Another use of metal for exterior work is found in the framework of skylights. These, if large, are made of light steel

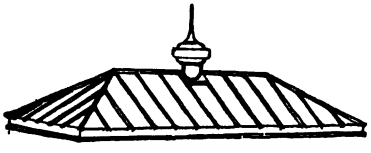


Fig. 198. Hip Skylight

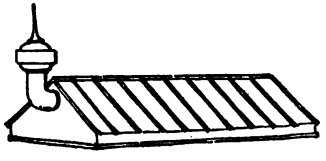


Fig. 199. Gable Skylight

angles or T-irons, and covered with sheet metal, sometimes with a lining in parts of terra cotta blocks. If the frames are of ordinary size, they are formed of heavy sheet metal, usually galvanized iron or copper, and they come in a variety of designs suited to different uses. The two principal forms of skylights are the hipped skylight, Fig. 198, and the gabled skylight, Fig. 199. All skylights should be provided with ventilators of some sort; often a greater circulation of air is obtained by building a vertical wall containing sashes or louver blinds.

Roof Houses. Roof houses, often necessary to give access to roofs or to house machinery, are constructed similarly to large skylights, but without the glazing or louvers in the walls. If more than 40 feet above the sidewalk, they must be, according to the building laws of many cities, of fireproof construction, and they are usually made of T-irons with a terra cotta filling covered with sheet metal, Fig. 200. It is essential that the T-irons be set with their flange inside or on the opposite side from the metal covering; otherwise the pounding-down of the seams of the metal will be likely to start the terra cotta out of place. On account of this pounding-down of the seams, it is often better that the blocks should be of solid terra cotta and not hollow tiles. The connection between these houses and the main roof must be taken care of as already described for roof and wall flashings, due allowance being made for expansion of the metals. It may be well to note here that zinc for

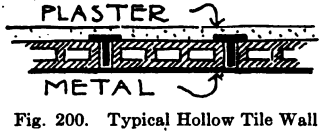


Fig. 200. Typical Hollow Tile Wall

flashings should never be used where it will come in contact with iron, lead, or copper, as this contact will produce voltaic action which would finally destroy the zinc.

FLOOR FRAMING

General Features for Various Buildings. The exterior wood framing of city buildings is in most cases confined to roofs, since no exterior walls within building limits of modern cities may be constructed of wood. Wooden roofs covered with slates or other fire-resisting materials are allowed, however, in many cities, up to a certain height above the sidewalk. The only difference which we shall find in this wooden construction from the suburban house considered in Part I is that usually the spaces to be covered are larger and the roofs, consequently, must be heavier. Floors also must be stronger, and because of the variety of city structures—from comparatively light buildings to heavy stores and warehouses—a great range in floor construction is required in their erection.

CITY DWELLINGS

For brick dwellings the floor construction differs little from the wooden houses already described, the principal differences being

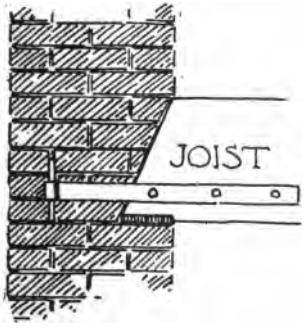


Fig. 201. Section Showing Beveled Floor Joists

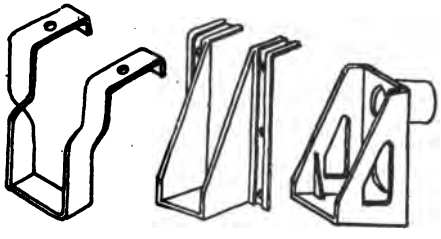


Fig. 202. Typical Joist Hangers

that the spans are greater and, consequently, the timbers are heavier, and also the fact that the outside bearings are taken by the brick walls instead of by wooden girts. The joists in this case should run on to the wall at least 4 inches and should be beveled at the end, so that in case of fire the floors may fall without destroying the wall, Fig. 201. The joists must be anchored to the walls about every

five feet with iron ties secured to the joist at the side, and low down, to allow the joist to fall out if burned. These ties should be continued across the building by tying the inner ends of the joists together and putting an anchor in the opposite wall, in as nearly a direct line across the house as possible. All large timbers, such as girders, should have anchors and should rest on cast-iron wall plates. Partitions carrying floors should have a stud set close against the brick wall and bolted to it, and all large openings, such as stair wells or skylights, should have headers hung to the trimmers by stirrup irons or patent hangers, shown in Fig. 202.

If there are openings in the brick walls which come so near to the bottom of the joists that an arch cannot be turned, a header should be cut in, or a steel beam inserted in the wall. Joists are sometimes fastened to the walls by hangers, and do not run into the wall at all; but while this preserves the full strength of the wall, it does not make so good a tie and is not generally done. The wall plate of a brick dwelling is usually made of a plank the thickness of the wall, secured by $\frac{3}{4}$-inch bolts which are built into the wall, as in Fig. 203. These bolts should run at least 20 inches down into the wall, and have a large washer plate at their lower end. When the wall has been brought to the required height, the plate is bored with holes to fit the bolts, and a nut and washer screwed on. Over the plate the rafters are notched, and the roof constructed as for a wooden house.

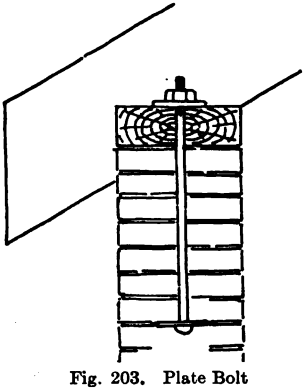


Fig. 203. Plate Bolt

STORES AND OFFICE BUILDINGS

In the construction of stores, warehouses, or office buildings, with wooden floors, the use of partitions for carrying the floor should be avoided, and columns and girders substituted. The reason for this is that under heavy loads the studding will often spring enough to crack the plastering, and, besides, the occupancy of this class of buildings by different tenants will require numerous changes in the partitions from time to time. The large girders and posts also offer

greater resistance to the action of fire, and permit fewer concealed spaces. Many city laws require the use of brick walls, trusses, or columns and girders, for support, if floor spans exceed 30 feet, and this is a good rule to observe.

Wooden Columns. In establishing a line of columns and girders, the columns should be spaced about 12 or 14 feet apart for wooden girders, a spacing that can be increased to 25 feet if steel girders are used. Solid wooden posts will last better, if bored from end to end through the center with a hole about $1\frac{1}{2}$ inches in diameter, and with a $\frac{1}{2}$-inch hole bored into the center at the top and bottom. This allows a circulation of air through the center of the post, and guards against dry rot, especially if the post is not thoroughly dry when set. The central boring should be done from one end, and if it comes more than an inch out of center at either end, the post will be weakened and should be rejected.

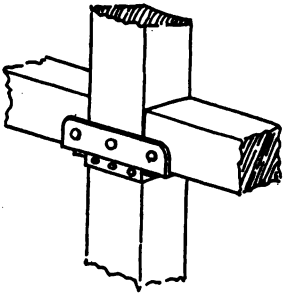


Fig. 204. Steel Post Cap

All wooden posts carrying girders and posts above, should have an iron cap with side plates to receive them, Fig. 204, so that the post above will be supported directly by the post below, and will not stand on the girder. This is necessary for two reasons. One is, that if the girder ran over the top of the post and the post above were set upon it, the shrinkage of each girder would be multiplied by each succeeding floor, and in a building of four or five stories this might amount to 2 or 3 inches; the upper floor beams at their inner end would then be that much lower than the outer ends which are supported by the rigid masonry. Another reason is, that the crushing strength of the girder in its longitudinal position is not so great as the post standing on end, and it might be unable to support the accumulated weight of several stories. This support was formerly obtained entirely by the use of cast-iron pintles, Fig. 205, which

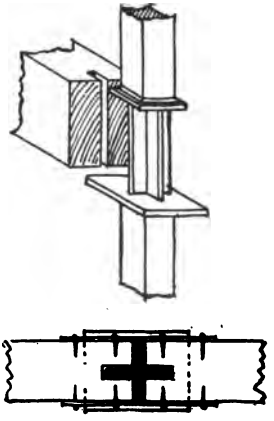


Fig. 205. Elevation and Plan of Cast-Iron Pintle

were molded with top and bottom plates to fit the posts, the weight being transmitted by the cross-shaped metal. This is an effective method, but has been superseded by the more modern steel caps. The bearing of the girders should be at least 5 inches on either end, and a box anchor of some kind should be used to support the wall end of the girder, as shown in Fig. 206.

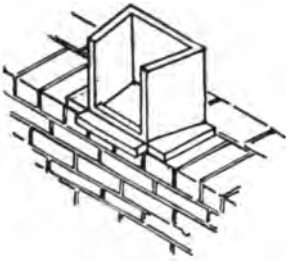


Fig. 206. Box Anchor on Wall

Iron and Steel Columns. For large spans and heavy weights it is often necessary to use iron or steel columns with wooden girders. If cast-iron columns are used, they should be made with a shell not less than $\frac{3}{4}$ inch thick. This is necessary on account of the danger of an unequal thickness in the shell. To obtain the hollow column, the casting must be made about a core, and although this core is accurately centered, there is danger of its being displaced by the pouring-in of the molten iron, since being of a lighter composition, it will have a tendency to "float". This may result in an added thickness to one side of the shell of the column and a corresponding lack of metal on the opposite side. To guard against this defect, cast-iron columns should always be tested by boring small holes on opposite sides, and if more than one-fourth of the thickness of shell is wanting in any column it should be rejected. The outer surface of cast iron should be smooth and clean, with sharp angles; and all projections, such as lugs, caps, or bases, should be closely examined to detect the presence of cracks.

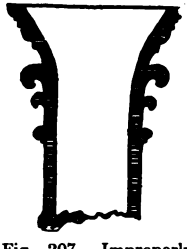


Fig. 207. Improperly Cast Column

Cap and Base. The top and bottom of all cast-iron columns should be turned off in a lathe to insure a bearing at right angles to the axis, and plates should be used to increase the bearing. These plates are cast with a ring or with projections to hold the column in place against movement, and they should be planed to a perfectly even bearing. The cap must never be spread out as a casting, Fig. 207, but should carry up the line of the column itself, all ornamentation requiring a great projection being cast separately and fastened on, Fig. 208. This allows the shaft of the column to run

straight up to bear the weight of the column above, while the girder is borne by the projections cast upon the column. The distance from the cap to the top of the column should be about four inches greater than the depth of the girder to give room for bolting the columns together.

With a wooden girder, the ends of the timber must be cut out to fit the diameter of the column, Fig. 209, and the girders must be tied across the cap by stout straps on each side. If steel beams are used, they can be tapped to the column plate or strapped together around the column.

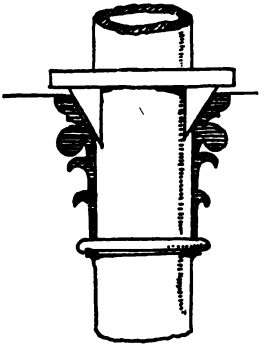


Fig. 208. Proper Application of Ornament to Column

Pipe Columns. Heavy wrought-iron pipe is often used for columns, a cap and base being sometimes cast and screwed on by a thread; and a patented column, formed by filling the pipe with cement, may be obtained ready-fitted with cap and base.

Wooden Girders. If wooden girders are used, they may be set wholly or partially below the floor timbers, or flush with them.

Girders below Floor Timbers. If there are no objections to dropping the girders below, this is the simplest and strongest construction. In this case, the floor beams should be sized down on the girders to maintain a perfectly level floor line, and a full bearing should be obtained for each timber. Where the girders are large, the timbers may be brought to butt against each other upon the girder; and they should be secured end to end by iron dogs which turn down into each timber, Fig. 210. For small girders and light timbers, it is better to let the timbers lap close and be spiked to each other, as in Fig. 211.

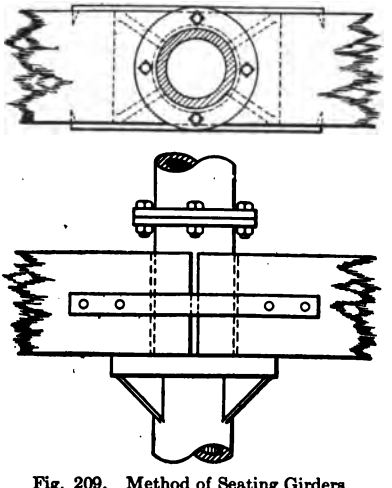


Fig. 209. Method of Seating Girders on Column

When the girders are near together, and the timbers long enough to span two divisions, a rigid floor may be obtained by breaking joints with the floor timbers every five or six feet.

Girders Flush with Floor Timbers. If the girders are to be framed flush with the timbers, the use of stirrup irons or patent hangers is recommended, as preserving the full strength of the girders. In this case the timbers on each side of the girder should be brought opposite one another as nearly as possible, and iron dogs long enough to reach over the girder and drive down into opposite timbers should be used, Fig. 212.

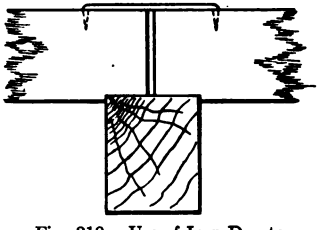


Fig. 210. Use of Iron Dog to Connect Large Girders

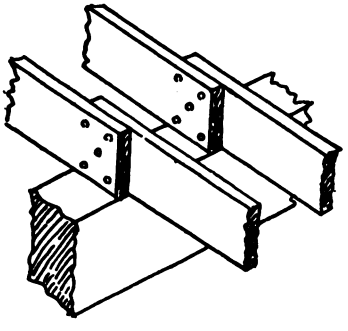


Fig. 211. Spiking of Joists

If the girder is deeper than the floor timbers, it may be set flush on top, and smaller pieces of hard pine or an angle iron may be bolted to the lower part of the girder in order to support the floor timbers, as shown in Fig. 213.

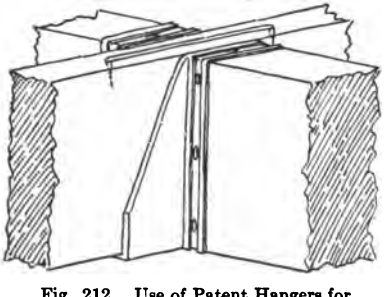


Fig. 212. Use of Patent Hangers for Joists Flush with Girders

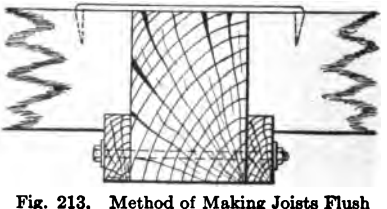


Fig. 213. Method of Making Joists Flush with Girders

Steel Girders. Where the spacing of columns has to be increased beyond the safe bearing of wooden girders, steel girders may be used. These usually consist of one or more steel I-beams, and they may be used with cast-iron columns or with steel columns. With cast-iron columns, the same methods will suffice as are used

for wooden girders, but with steel columns a different method of construction is necessary, which it will be better to consider later in connection with steel framing. It may be properly said here, however, that the use of steel girders and steel columns, even if the floor timbers are of wood, is to be recommended for high buildings and for buildings which are subjected to the jar of machinery. The reason for this lies in the greater rigidity which is possible in the girder and column connections, and the greater ease of bracing this construction.

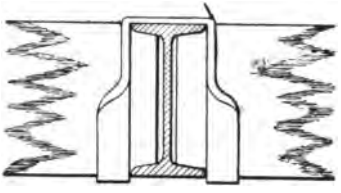


Fig. 214. Use of Stirrup Iron with Steel Girders

With the use of steel girders new considerations arise. If a single girder is set entirely below the floor timbers, it will give a better bearing if the timbers lap and spike to each other. With two or more girders, the timbers may be brought end to end as on the heavy wooden girder. If the steel girder is set flush with the timbers, the latter may be cut so as to run into the trough formed by the flanges of the girder, but they should be supported by stirrup irons or hangers, Fig. 214, as the sloping flange of the steel girder does not afford a good bearing. If the steel girder is deeper than the floor timbers, a common method is to bolt a timber to each side for a bearing; an angle bar can, of course, be used in the same manner, Fig. 215. In any case, the floor beam should be fastened so that there is no danger of slipping out of the hanger. Most of the patent hangers have a lug, or bolt, to secure the timber in place, and where timbers come opposite to one another, common iron dogs turning down into each timber may be used.

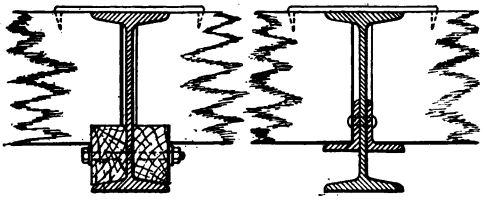


Fig. 215. Fastening Wood Joists to Steel Girders Using Wood Bearing Timbers or Angle Pieces

Crowning of Floor Timbers. All floor timbers having a span of more than 16 feet should be crowned, that is, the top of the joist should be cut to the shape of an arc of a circle, having a rise of $\frac{1}{4}$ inch to every 16 feet of span. This is necessary to allow for the ordinary sag of the timber, so that a level floor will result.

Supervision of Floor Framing. The supervision of the framing of floors of brick buildings calls for constant vigilance on the part of the superintendent. Not only is it necessary to follow closely the work of the carpenters, but the fact that the mason work is being carried along at the same time by a different set of workmen demands a great deal of forethought in order to bring the different parts together at the right time. The anchoring of floors properly, and at the proper time, requires constant attention, and the setting of plates, the building-in of bolts and hangers, and the leveling-up of floors and walls to their relative positions necessitates harmonious action between mason and carpenter.

In heavy framing, careful watching is essential to see that all necessary connections are made between post, girders, and floor beams, and that ties, straps, and bolts are set and tightened. If trusses occur, they should be strained up tightly when built, and kept tightly strained as long as there are any workmen remaining at the building, as the shrinkage of the timbers often loosens the joints and allows sagging to occur.

SLOW-BURNING AND MILL CONSTRUCTION

Slow-Burning Construction. The methods of heavy timbering recently described, with floors of matched or splined plank, and with no wood partitions or furrings enclosing hollow spaces, constitutes what is generally termed slow-burning construction. To obtain the best results from this method of construction, wooden girders should always be set flush with the floor timbers on top, as the dropped girder with the space above will permit flames to lap around the timber so that it will be more quickly consumed than if it is flush with the rest of the floor beams. Greater protection is obtained by covering the wood with plaster on metal laths, leaving no air spaces between the plaster and the wood.

Mill Construction. As its name indicates, mill construction belongs to the particular methods of building which have been devised for resisting fire and for sustaining the loads and shocks of machinery to which manufacturing structures are particularly subjected. This requires primarily the disposition of the timber and plank in solid masses, so that the fewest number of corners will be exposed to the action of fire, the separation of floors by fireproof

stops, automatic arrangements for closing hatchways and elevator openings, and incombustible partitions for enclosing stairways.

Beams. The typical construction employed for the mills of New England, and the only form acceptable to the insurance companies of that section, calls for posts at least 10×10 inches, spaced about 8 feet apart in the length of the mill and 24 or 25 feet across. Instead of a line of girders running lengthwise over the line of posts, the floor beams are laid across the mill on the top of the posts. These beams are usually 12×14 inches, or in two pieces each 6×14 inches, bolted together with an air space between. The wall ends should rest on iron plates, and the ends should be beveled off and secured only at the bottom, so that they may fall out easily if burned and not pull down the wall, Fig. 216. These beams are supported by iron post caps or pintles, as already described.

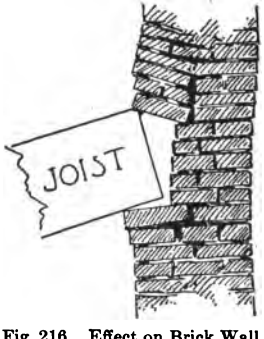


Fig. 216. Effect on Brick Wall of Not Beveling Floor Joists

Flooring. The flooring consists of a layer of 3-inch planks not more than 10 inches wide, splined together and blind-nailed; it should be long enough to span two spaces, breaking joints every 4 or 5 feet. All of this construction is usually of Georgia pine.

The upper floor is generally made of hardwood, such as maple or birch, and this is laid with square edges over two or three thicknesses of paper, each layer being mopped with tar, asphalt, or some similar material; sometimes a layer of plaster is spread between the upper and under floors.

Partitions. Where slow-burning or mill construction is used for the floors of a building, the partitions should be made of solid plank, plastered on both sides on metal lathing, or else of light steel framing with metal lath and plaster.

Roofs. The same methods of framing may be employed for the roofs as for the floors, but lighter timbers can be used, set to the required pitch, with a tar and gravel or metal roof. Sharply pitched roofs may also be constructed in the same way, the timbers being trussed if the span requires it.

Adaptation to Mercantile Buildings. This style of construction may be adapted to the use of mercantile or office buildings, but the

general requirements of this class of buildings do not allow posts to be placed so often as every 8 feet. This necessitates the use of girders and intermediate beams. If these beams are spaced 4 or 5 feet apart, it permits the use of 2-inch plank which may be tongued instead of splined. With the increased spacing, the posts must be made of iron or steel for a building four stories or more in height; and if the posts are more than 14 feet apart, it will be cheaper and better to use steel beams for girders. In this case all weight-bearing metal must be protected by at least an inch of plaster or other fireproof material.

FLOORING

WOODEN FLOORS

Rough Floor. As soon as the floor timbers are in place, it is the custom generally to lay a rough floor. This makes a platform upon which subsequent operations are carried on and also forms the foundation for the upper or finished floor. The character of this rough lining floor depends upon the nature of the floor framing. If it is of slow-burning or mill construction, with the beams far apart, plank must be used, of varying thickness according to the spacing of the beams. For a spacing of 4 or 5 feet, 2-inch plank may be used, but a spacing of from 5 to 8 feet requires 3-inch plank. This planking should be matched or splined and securely nailed to every bearing; if it is laid diagonally, it adds to the rigidity of the building and gives besides an even surface upon which to lay the finished floor.

For the under floors of dwellings or other buildings of ordinary light construction, $\frac{7}{8}$-inch hemlock or pine is generally used without matching. The boards should be mill-planed to an even thickness and as narrow as can be readily obtained. They should be securely nailed to every bearing, and laid close to the exterior walls, covering the surface completely, with no large holes or wide crevices.

Finished Floor. The laying of the upper floor should be delayed until the rooms have been completed up to the hanging of the doors. For floors that are to be carpeted, spruce or pine is generally used, and this may be laid without matching. For floors not carpeted, hardwood should be used, the boards sawed into narrow widths, matched, and blind-nailed.

The floors of kitchens, offices, and other places where much wear will come and where the expense of oak or other fine woods is not desirable, may well be of rift Georgia pine. Birch and maple also make good floors and have satisfactory wearing qualities. When laid on sleepers securely bedded in concrete, with no chance for the air to get beneath the floor, they are in little danger of being consumed by fire. In parlors, halls, and for parquetry flooring, oak is used to a great extent, either by itself or in combination with other fancy woods.

Wooden floors should be matched and tightly laid, and treated with as little oil or inflammable varnish as possible, depending upon constant care for preservation rather than on a great amount of finishing. All hardwood flooring should be quarter-sawed. The usual thickness of flooring stock is $\frac{7}{8}$ inch, but for stores, factories, and public buildings $1\frac{1}{8}$-inch or $1\frac{1}{2}$-inch stock is advisable.

Stock. Spruce and pine floorings are carried in two grades—first and second quality. First quality is free from knots, while second quality has small and tight knots.

Hard-pine flooring is rated as rift, quarter-sawed, first and second clear, and star. Only rift hard pine should be used for a good floor, as slash boards split and sliver. Oak flooring should always be quarter-sawed, and this, as well as all other hard woods should be in narrow widths, $2\frac{1}{4}$ inches being as wide as should be used for the best floors. First-class flooring is usually grooved on the under side to lie close to the rough floor, and should be matched and blind-nailed for good work. For offices and factories square-edged boards wear better and permit renewal more easily than does matched flooring. Floors laid diagonally or across the under flooring lie more smoothly and remain closer than if laid the same way as the under floor. If the added stiffness is desired for mill floors and it is not convenient to lay the floor diagonally, a degree of stiffness may be gained by laying the floor square and nailing it in diagonal rows.

Paper and Deadening. Between the upper and under floors paper should be laid, and a deadening of plaster, quilt, or mineral wool may be used. For mill and factory floors it is desirable to use two or three thicknesses of paper, mopped with tar or asphalt.

TILING

Preparation of Floors. Where the upper floor in wooden construction is to be of tiling or mosaic, special preparation is needed to obtain a thick bed of concrete or bricks under the tiles. To do this the rough floor must be let down between the timbers, and supported by strips nailed to the sides of the floor beams, as shown in Fig. 217. A bed of at least 4 inches should be provided, and the beams cut off to a bevel on top as shown. Even then there is a tendency for the tiles or mosaic to develop a crack over the beams, and so metal lathing is often used to prevent the concrete bed from cracking. This preparation is necessary for old floors which are to be tiled, or for new floors only a portion of which is to be covered with tile; but when the whole of a new floor is to be tiled, and there is nothing to prevent, it is better to set the floor timbers enough below the finished level to give the required bed, Fig. 218. Narrow boards should be used, laid $\frac{1}{8}$ inch open to allow for swelling. To prevent the moisture in the concrete from being absorbed too quickly by the boarding, and to guard against dripping, two thicknesses of tarred paper may be spread over the whole surface of the floor before the bed is laid; sometimes the use of corrugated metal lathing is advisable.

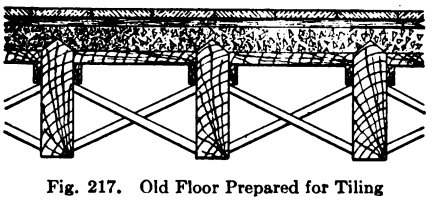


Fig. 217. Old Floor Prepared for Tiling

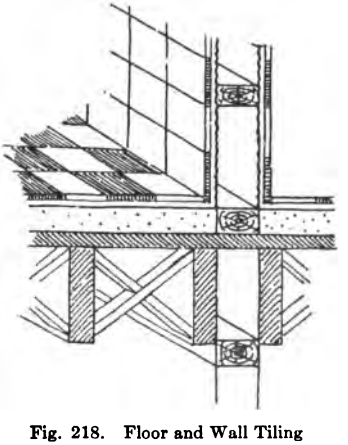


Fig. 218. Floor and Wall Tiling

The preparation of wooden walls for tiling is more simple. Here it is only necessary to provide a firm and continuous sheet of plaster upon which the tiles are to be bedded. This may be done by cutting in between the studs horizontal pieces 2 inches by the width of the studding and about a foot apart, upon which metal lathing is nailed; a rough layer of cement mortar (use hair in the mortar) is spread upon this, with room allowed for the proper bedding of the tiles, Fig. 218.

Laying Tile. Tiles of various patterns and materials are used to a large extent for floors and walls of bathrooms, corridors, and counting rooms. For fireplaces, and walls and floors of bathrooms, where the tiles are not subjected to hard wear, a plain glazed tile makes a clean and satisfactory job, but where much wear will come, the hard, vitreous, unglazed tiles give a better wearing surface.

The foundation for tiles should be prepared from the best Portland cement; it should be perfectly level and allowed to harden thoroughly before the tiles are laid. The foundation for both floor and wall tiles should be carefully brushed, to remove all dust and other foreign substance, and then well wet before the cement bedding is applied. Portland cement should be used for setting floor or wall tiles, and for grouting the floors, and the best Keene's cement for filling the joints in wall tiling. Clean sharp sand, well screened, should be used in equal parts with the cement for floors, and with 2 parts sand to 1 of cement for walls. The tiles must be thoroughly soaked in water before setting.

Floor tiles are set by being firmly pressed into the mortar bed and then tamped until perfectly level. When the bed is sufficiently set, the joints are grouted with pure cement and cleaned off with sawdust or fine shavings.

Wall tiles are set by two methods, called *floating* and *buttering*. In floating the tiles, a portion of the bed is spread on the wall, and the tiles placed in position and tamped until firmly united. Buttering consists in spreading the mortar on the back of each tile, which is then placed against the prepared wall and tapped gently until it is united with the bed. When the tiles are all set, by either process, the joints are carefully washed out and filled with cement. When fixtures are to be secured to the walls, as for plumbing, etc., a wooden piece should be fastened to the wall, flush with the rough bed, and the tiles laid over it, to be bored for the fastenings.

Mosaic Tiles. These are small tiles of various patterns adapted to laying in special designs or borders, and for this purpose are mounted on sheets of paper of a size convenient to handle. In setting the mosaic tiles, the sheets should be first examined to see that the design is right. The sheets are then laid carefully on the mortar, with paper side up. After the space is covered, the tiles are pressed into the bed, being beaten down with a block and ham-

mer until the mortar in the joints is visible through the paper, without, however, breaking it.

In laying the sheets, care should be taken that the joints between the sheets are spaced the same as those upon the sheets, or the uniform effect of the floor will be spoiled. In large areas every third or fourth row of blocks should be set to a chalk line to preserve the straight line of the tiles.

After being laid the paper is moistened, and when thoroughly soaked it can be easily removed. When the paper has been removed, the tile should be sprinkled with white sand, before finishing the beating, so that the softened paste will not cause the tiles to adhere to the block. The whole surface is then brought to a perfect level. When the floor is leveled, the joints are filled with clean Portland cement mixed with water and forced in with a flat trowel, the surplus cement being removed from the surface by drawing a wet piece of Canton flannel over it. After the cleaning, the floor should be allowed to stand for a day or two, and then it is rubbed with sharp sand and a board of soft lumber to remove every trace of cement on the surface.

Protection of New Floor. All floor tiles should be protected for several days after being laid, and if it is necessary to walk upon them, this protection should consist of a heavy coat of sawdust upon which boards are placed. A white scum sometimes appears upon the surface of colored tiles, due to the cement. This can generally be removed by careful washing with soap and water. If washing does not remove the scum or the dirt, a dilute solution of muriatic acid (6 ounces of acid to a bucket of water) may be applied with a scrubbing brush and allowed to remain on the floor for a few minutes only, when it should be thoroughly washed off.

COMPOSITION AND LINOLEUM

If something other than wood is desired, floors of composition or linoleum may be applied either to the structural concrete floor or to a wooden floor surface. Composition floors having a base of cork, asbestos, asphalt, or other suitable medium, are laid in plastic form, usually from $\frac{1}{2}$ to $\frac{3}{4}$ inch in thickness over new or old floors, making a continuous covering. The principal requisites are that the floor shall be fireproof, resilient, non-slippery, quiet, and dur-

able. Installation is generally made in two layers, the first one of a softer material, the top one hardened for a wearing surface.

Method of Laying. Composition flooring does not adhere to wet concrete and should not be applied until the rough floor is bone-dry, nor unless the building can be heated to approximately 70 degrees. The floors must be left by the contractor in a finished and polished condition and they should be given the same care and attention as a first-class hardwood floor; like hardwood floors, also, the laying of the composition floors should be deferred as long as possible in the finishing of the building. They should be carefully protected when first laid and should not be given any hard usage until thoroughly cured. This requires, according to the condition of the building, from 3 to 5 days.

Colors. The colors which have been found best adapted to composition flooring are rather few in number; red, buff, black, and gray are the staple colors which the manufacturers seem willing to guarantee not to fade, although green is used with a varying degree of success. These colors can, of course, be laid in combinations to suit the fancy.

Flooring Made in Units. There is another form of composition flooring which consists of slabs, or units, made up in square, oblong, and other shapes, some interlocking by joint or pattern. These tiles are usually $\frac{1}{4}$ inch in thickness and are laid in a waterproof cement made specially for this purpose.

Rubber Tiling. Rubber tiling, usually in an interlocking pattern, Fig. 219, is laid in a similar manner and makes a very durable floor, the resiliency of the rubber preventing a great degree of wear, while the elasticity insures it against cracking. All of these made-up floors are provided with a coved or sanitary base, if desired, and they are all adapted for use on stair treads and other places which are subjected to extreme wear.

Fig. 219. Rubber Tiling of Interlocking Pattern

Use in Dwellings. Composition flooring of the same nature as that described for office buildings may be used to advantage for the service parts of a dwelling house. In selecting a floor of this kind for a dwelling, certain qualifications which are not of great

importance in office floors should be well looked into; not only the wearing qualities, but imperviousness to heat, cold, and moisture, elasticity for foot comfort, ease of renewal or repair, besides weight and fire-resisting qualities, should all be considered, and—by no means the least important—appearance and ease of care. The plastic or monolithic type is to be preferred. If a wainscot or high base of the same material is required, this must be taken into account, and the proper spacing of studs and other requirements attended to by the superintendent. It will be necessary to see that unhampered facilities are given the workmen to apply the flooring evenly and continuously, and that ample time is allowed for the floor to harden, before it is walked upon or otherwise tested. Linoleum may also, if preferred, be used to good advantage on such floors.

WOOD-BLOCK FLOORS

Description of Blocks. For heavy warehouses, basements, stables, etc., a good wearing floor is obtained by laying wood blocks similar to street paving blocks. These blocks are made in rectangular or hexagonal shape, thoroughly shrunk, and impregnated with creosote or some similar preservative. The rectangular blocks are sometimes made with V-shaped lugs in projections on one end and side, running with the grain of the block and projecting about $\frac{1}{4}$ inch. This lug is of advantage in defining the joints and also in taking up any expansion from the swelling by the V-shaped edge, which will become compressed and not exert a thrust upon the walls of the building.

Method of Laying. The blocks are usually from $2\frac{1}{2}$ to 4 inches in depth (parallel to the fiber) and in random lengths, from 6 to 10 inches, and they should be laid over a concrete bed, on a cushion of sand about $\frac{1}{2}$ inch in thickness. After eight or ten rows of blocks have been placed, breaking joints, a plank is laid along the edge of the course and the blocks driven tightly together, the process being repeated as the laying of the floor progresses.

When a reasonable amount of floor has been laid, the blocks are tamped to a true and level surface and the joints filled about one-half full with sharp sand. A bituminous cement is then poured on and "squeeged" into the joints until they are completely filled. A sifting of dry sand should then be spread over the surface of the

blocks to prevent sticking. If too much cement is found adhering to the surface of the blocks, it may be removed by applying coarse heated sand to the surface, the whole being then scraped off and the blocks left clean.

SPECIAL FEATURES OF OFFICE BUILDING CONSTRUCTION

Counters. For banking rooms and corporation offices, counters of greater or less extent and elaboration will be required. These are often made of wood but they may be constructed of other materials, a wooden top being sometimes preferred. Enameled bricks or tiles for the base of counters with wooden tops make a solid structure, while polished marble of almost any cost may be used. Where there is danger of a marble top being spattered with ink, a plate glass top, either clear or opaque, is often put over the marble, and in some cases, especially in the public portion of banking houses, sheets of heavy plate glass supported on metal frames are used. In the case of glass tops where coins are to be passed, the glass should be arranged so that the portion where the coins are passed can be easily replaced, as it will soon become scratched and present a bad appearance. Clear plate glass supported on a light metal base makes a good counter for rooms which are somewhat small, as it appears so much less bulky than a solid counter.

Grille Work. An important feature of a modern building is the grille work made of various metals and used for protection and decoration.

Exterior Grilles. For exterior ornament or protection, grilles will be found principally in door or window openings, and in this application, wrought-iron grilles are generally used. Window grilles are usually set in the depth of the stone or brick jamb of the window, as in Fig. 220, but they are sometimes put over the opening on the outside face of the wall. This is the customary way if the window is small, Fig. 221. The fastenings of grilles should be secure and lasting; and the grilles should be set in a rim of iron with

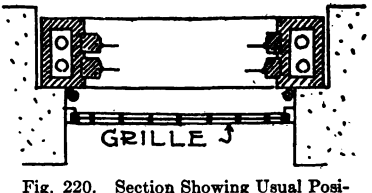


Fig. 220. Section Showing Usual Position of Window Grille

hinges and locks, to give easy access for cleaning the windows, Fig. 222.

Door grilles are sometimes glazed on the back with plate glass, to form a weatherproof door having the effect of the grille; when this is to be done, care must be taken to bed the glass carefully, as the expansion and the jar of closing are likely to crack it.

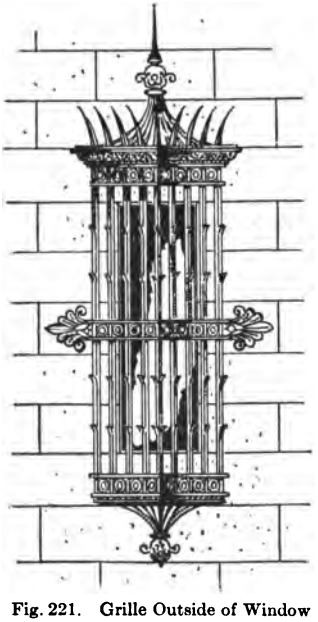


Fig. 221. Grille Outside of Window

Interior Grilles. Interior grilles are used chiefly in the protection of elevators or lifts, and to exclude the public from the working portions of offices and banks. Elevator grilles are generally made of wrought iron, and they should be at least 7 feet 6 inches high on the sides and carried from floor to ceiling in front of the doors of the car. All portions within easy reach of the public, where there is danger that the hand might pass through, to be injured by the moving parts of the elevator or counterweight, should be of a fine pattern or protected by fine netting. The main support of the grilles is found in the corner posts which support the elevators, or the stairs which often enclose them on three sides, and the pattern of the grille work should be stout enough to stand rigid between these posts.

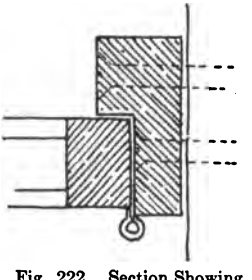


Fig. 222. Section Showing Hinging of Grille

The counter and office grilles are often made of thin steel, bent into various patterns and riveted together, a method of construction also used for elevator cars where lightness is a valuable feature. These grilles are finished by plating with copper, bronze, nickel, or other metal, and can be given almost any desired tone. Although these do not compare in appearance with wrought-iron grilles, they are less expensive, and more quickly made, and are readily obtainable from the manufacturers in a variety of stock patterns.

Wrought-iron grille work of all kinds should be carefully inspected to see that the scrolls are well turned, that welding or riveting is neatly done, and that the whole section is tightly put together. Cast-iron patterns must be inspected for smoothness and clearness of the ornamental sections, and an even thickness of metal should be required for all similar parts.

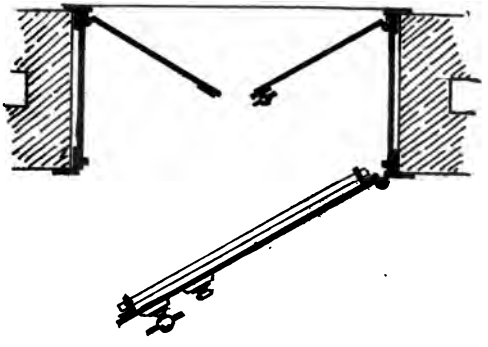


Fig. 223. Door of Fireproof Vault

Fireproof Vaults. All banking and large commercial offices require a fireproof vault of some sort for the preservation of valuable records as well as money. These vaults, in a building of ordinary construction, are easily made of bricks and steel beams. The vault, in principle, consists of a thick wall of bricks with proper air space and covering, enclosing a space of greater or less extent, access to which is given by a double set of doors, separated by the width of the wall at least, and securely fastened from without. To withstand the effect of a conflagration, the walls should be double, having an inner wall of 8 inches of brick, then an air space of 4 inches, and an outer wall of at least 8 inches of brick, both walls being tied together across the air space, which should be ventilated top and bottom. This gives a wall 20 inches in thickness and allows a door to be made with the outer valve in one leaf and the inner door in two parts, these parts opening into a vestibule formed in the thickness of the wall, Fig. 223. The top must be covered with bricks laid on iron bars or beams, and must be at least 20 inches thick to withstand the heat and the falling of beams or masonry, Fig. 224.

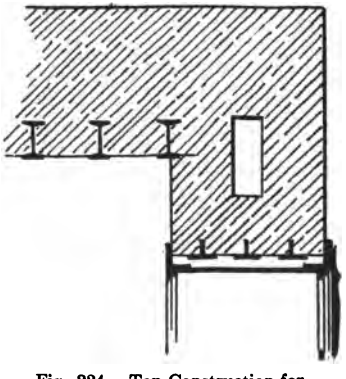


Fig. 224. Top Construction for Fireproof Vault

Burglar-Proof Construction. Vaults of this construction are fireproof but not burglar-proof, the latter advantage being obtained by a lining of chilled steel or a separate burglar-proof safe set within the brick vault. Vaults have also been made burglar-proof by constructing them of concrete in which are imbedded enough old iron or steel bars or rods, to make it a slow and difficult process to effect an entrance of sufficient size to extract any part of the contents. Copper wires are sometimes laid in the concrete at intervals of 3 inches or less, connected with a battery which rings an alarm bell if the wires are tampered with.

Store Windows. The present-day desire to have as much plate glass as possible in store windows has led to the development of a special construction, with the object of reducing the necessary

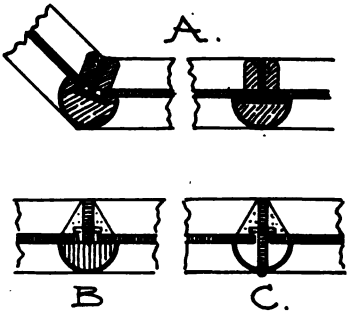


Fig. 225. Sections of Special Sash for Ordinary Store Windows

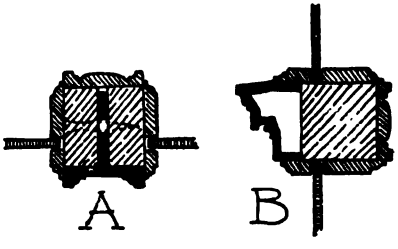


Fig. 226. Section of Window Bars for Large Plate Glass Windows

supports of the glass to a minimum. For ordinary store windows, where the lights are not more than 6 feet wide, the bars may be made of a common T-bar covered by a half-round of nickel-plated brass over a wooden form, *A*, Fig. 225, the glass being set from the inside, and held in by pins and putty or wooden stop beads. Sometimes a half-round bar is screwed to a web piece of iron, and the outside painted or covered with nickeled brass, as at *B*, Fig. 225. Another form giving greater strength of web is shown at *C*.

For larger lights, a special method which will give greater strength is required; this is often secured by means of a special casting exposed and ornamented on the front, but otherwise concealed in the wood finish, as at *A*, Fig. 226. These castings should be about 2½ inches wide by 3 inches deep, depending upon

the size of the glass, and the glass may be set either from the outside or the inside, and held in place by molded stops, made of metal on the outside, if desired. If transoms are used, they may be of the same section as any of the bars, or a more ornamental form may be given, *B*, Fig. 226.

The top of the window usually has the same section as the sides, and the sill depends upon the character of the show window and whether or not the sash comes to the floor. If a bulkhead is required with cellar lights under it, a section similar to that shown in Fig. 227 is often employed. To prevent the windows from becoming frosty in cold weather, ventilating openings, through which the condensation may drain out, are provided, and also a trough to connect with these openings. Basement sashes should have wooden sills fitted over a lip in the iron or concrete of the sidewalk, or bedded tight if the sidewalk is of stone or brick.

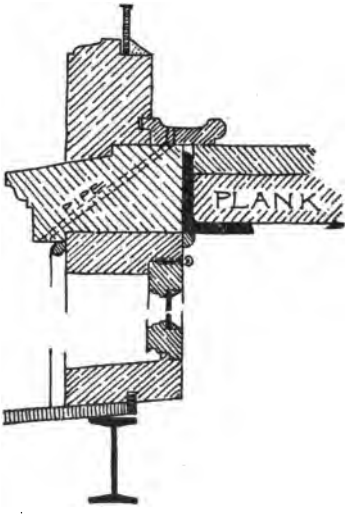


Fig. 227. Section of Sill of Store Sash

The corners of store windows may be treated by adapting any form of bar to the angle, and where it is of advantage to show no bar at all, the two sheets of glass coming together at an angle may be made to support each other by clamping them together with no dividing bar. Several patented forms of connection may be used for this, as well as for the dividing bars. In setting large lights of plate glass, a backing of rubber or leather should be used in place of the usual back puttying.

Sidewalk Lights. It often happens that space under the sidewalk is needed to add to the area of the basements, and this is usually permitted by city ordinances. Then the question of introducing daylight comes under consideration. Many types of sidewalk or vault lights may be obtained, differing as to support, form, and glazing, and running from the original type of round bull's-eyes set in a cast-iron plate to the most modern construction of composite

nature. The principal features to be considered are admission of light, exclusion of water, and minimum of breakage, the breakage being generally caused by accident, poor glass, expansion or vibration of the construction, or pressure from the street adjoining.

The ideal light is consequently a strong glass of good size set in a construction that combines elasticity with rigidity against outside pressure. This is best obtained by the use of concrete and steel, in some one of the many forms now on the market, which differ from each other mainly in the shape of the glass, the method of reinforcement, and the ease of setting or replacing the glass in case of accident.

As between square or round glass, it is well to remember that while the square glass gives a comparatively greater light area, the round glass is in many cases more easily replaced, and this in some situations is an important feature. The accidental breaking of a glass cannot be avoided, but to guard against general breakage, some one of the systems that provide for expansion or afford a protective cushion for the glass is well worth considering.

Prismatic Glass. For the better lighting of deep interiors or places where the available supply of direct light is limited or distorted, prismatic glass is to be recommended. This glass comes in sheet form or in the shape of tiles, usually set in a metal rim or sash. The effective use of prismatic glass requires that each job shall be treated scientifically in accordance with its needs, a haphazard installation being productive of waste and dissatisfaction.

For a successful result, a careful study is made of existing sky conditions, and prisms of a correct angle properly to diffuse or concentrate the light are put in place. In cases where the visible sky area is limited, as at the bottom of shafts or light areas, it is often necessary to install a canopy of prisms, projecting from the wall at a correct angle and containing prisms having the proper degree of refraction to throw the almost vertical rays into the room. This situation is one of the most difficult to contend with; a deep building having a broad exposure to unobstructed daylight requires simply the refraction necessary to change the direction of the normal oblique rays to a more horizontal and penetrating angle.

As to the choice between sheet prisms and the so-called tile prisms, the advantage in appearance rests with the tiles or quar-

ries, while in the matter of cost the sheet glass has the advantage. The small lights in metal setting produce a fire-resisting screen, while with large lights the type known as wire glass, which has a wire mesh imbedded in the plate, meets the usual fireproof requirements.

Another use of prismatic glass is found in sidewalk lights, but these are of a special type and are generally found in the form of a single prism as distinguished from what is generally called prismatic glass.

Revolving Doors. For stores or public buildings where the passing of adults is steady but not excessive, it may be well to install revolving doors as a protection against the cold. These consist of a turnstile arrangement of doors, having three or more wings, built in a vestibule with curved sides and so adjusted that at least two of the wings make a continuous barrier from one side of the vestibule to the other, Fig. 228.

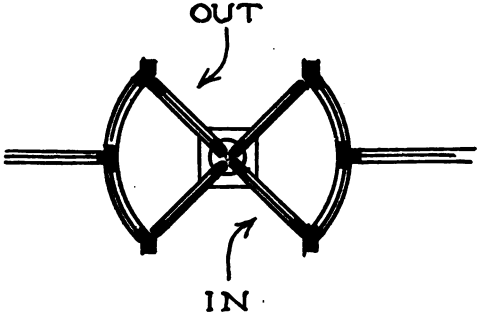


Fig. 228. Section of Revolving Store-Doors

Wherever used, the doors should be of the automatic panic-proof type in which the revolving wings are so arranged that a pressure slightly more than is required to revolve the doors, when applied to any part of any two of the wings, will cause them instantly and automatically to collapse and fold outward. The wings should also be built so that they can be collapsed and moved to one side to give free passage in mild weather, or locked across the vestibule for security. Where the doors come in contact with the walls of the vestibule they should be provided with ample flexible strips to prevent injury to the hand or person.

Mail Chutes. For the convenience of the occupants of offices above the first floor, any office building of size should have the system of mailing letters by means of a specially constructed chute connected with the mail box at the bottom. The location of the chute should be determined early in the course of construction and preparation made for it. The system, which is patented, must be

installed subject to the approval of the local postmaster, and all the apparatus, when erected and accepted by the Post Office Department, passes under the care and control of the government, which authorizes the locks and boxes. The boxes are of various sizes and patterns, and are furnished by the makers of the chutes. Government regulations require that the chutes be in movable sections, exposed to view and easily accessible, and stipulate that they may be run only in the public hall or corridors of a building. The chute must be made of metal with a plate glass front, clearly marked with the insignia of the department; when so installed it is technically a part of the mail box below.

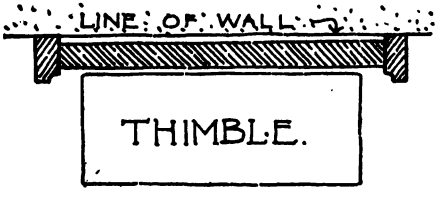


Fig. 229. Backing of Mail Chute against Wall

The requirements for the support of the chutes are a continuous vertical surface $10\frac{1}{2}$ inches or more in width, carried from the box below to a point not less than 4 feet 6 inches above the top of the highest floor to be supplied. In front of this vertical run must be set the iron thimbles provided by the makers, $3\frac{5}{8}$ inches by 9 inches, the whole absolutely plumb, with no bends or offsets anywhere.

For wooden buildings a flat casing of wood may be used, or marble or other costly material may be substituted, wholly or in part. This construction is generally used where the chute runs against a wall, as in Fig. 229. Where the chute runs down beside an elevator grille, or in other places in which a solid back would be objectionable, two "square root" angle irons are generally used, turned so as to give an even backing, Fig. 230, the thimble in all cases being the same, and the angle irons being secured to the floor beams or other rigid support.

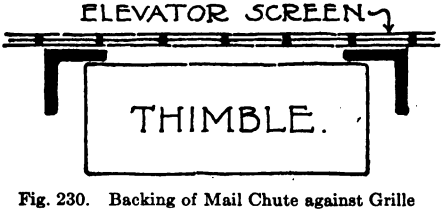


Fig. 230. Backing of Mail Chute against Grille

This preparation may be made a part of the building contract or of the mail chute contract; in either case it will have to be done to the satisfaction and acceptance of the makers of the chutes and of the local Post Office authorities.

FIREPROOF BUILDING

IMPORTANT QUESTIONS FOR PRELIMINARY STUDY

The most modern features of city building construction are the high business blocks which form the main part of the commercial districts of all cities. In the erection of these buildings a variety of problems present themselves, more or less complicated according to the nature of site and surroundings, of size, and of usage.

Land Values. In the first place, the value of the land which the proposed building will occupy must be considered. Real estate in the heart of our large cities attains almost fabulous value, and the first demand which the owner will make, will be the maximum of rentable area within the walls of his building. This of itself will force us to adopt a system of construction which will permit the thinnest walls that safety justifies and the building laws allow, and the same consideration will force us to build as high as possible. From these tendencies has arisen the modern skyscraper, a construction consisting of a steel skeleton, covered with masonry simply as a protection for the steel and for the contents of the building, and having no weight-bearing value in itself. The floors and walls are supported wholly by the steel frame, which is carried usually on isolated supports far below the sidewalk. This is the common form of high building and is known as skeleton construction.

This type of construction is fully treated in Part III, so that mention need be made here of only some important details which affect mercantile buildings in relation to the general layout of the plan.

Height of Buildings. As the owner will naturally desire to obtain as many floors as possible, it will be necessary to consult, first of all, the building laws of the city in which the structure is to be erected, to determine the height to which the building may be carried. This determined, the number of floors must be decided. As the lower floors are less likely to be subdivided than the others, they must be given a height which will be in proportion to the probable size of the rooms; the height of the lower stories must, therefore, be added together, and the sum, with the addition of the thickness of the floors, must be taken from the whole height of the building before we can establish a unit of height for the remaining stories.

Building Site. While these matters are under consideration by the owner, an examination of the proposed site will be profitable, to gain necessary information with regard to party walls and the condition of adjoining property. The nature of the soil and the location of sewers and other underground works, will be factors in the proposed construction, and all data relating to these matters must be recorded and carefully preserved.

General Construction Problems. *Vertical Supports.* As soon as the instructions of the owners, or the recommendations of the architect, have been definitely adopted, the construction of the building will be laid out. Certain factors, which do not enter so strongly into the problems we have previously studied, must have careful attention in constructing mercantile buildings of this class, and upon our skilful management of them will depend the success of the enterprise.

As the problem will resolve itself into the disposition of a greater or less number of isolated points of support, instead of the ordinary continuity of walls, it will be necessary to study the construction at the same time with the laying-out of the offices in order to place the necessary vertical supports as much out of the way as possible.

Thickness of Floors. Another matter of importance will be the thickness of the floors. Since the number of floors is certain to be considerable, it will be readily seen that an excessive thickness would result in an appreciable loss of height; if the thickness of each floor can be kept down to a reasonable rate, it may be the means of obtaining one more story for renting purposes, which is a matter worthy of consideration.

External Factors. In bringing together the elements to form a whole composition, certain external conditions must be taken into account. Among these are ease of access, maximum of light, rentable area, ease of rearrangement to suit tenants, and minimum of cost. Ease of access requires that the elevators and stairs shall be placed in direct and obvious connection with the entrances and as nearly as possible at the level of the sidewalk, that they may be readily seen on entering the building or on leaving the offices to which they lead. The position of the elevators is of more importance than the stairs, as the latter will be little used in high buildings. To obtain the best light possible it is well to provide that the

areas (which are a necessity in a building in the interior of a block or in a wide building on a corner) shall have a general direction north and south. These areas should contain windows as large and as near the ceiling as possible, and the rooms should be as nearly rectangular as may be, to avoid dark corners.

The structural conditions determine more or less the arrangement of the offices, as already suggested, but the adjustment of the office space to the needs of the tenants is a matter that must also be given consideration. The unit of size and the arrangement of the offices should be such that the tenant who wants a single office may have one of average size, and the tenant who wishes may have a whole floor, except the minimum of space necessary for toilets, elevators, and stairs.

FLOOR CONSTRUCTION

When the character of the building and the general divisions of the floor space have been established, the location and design of

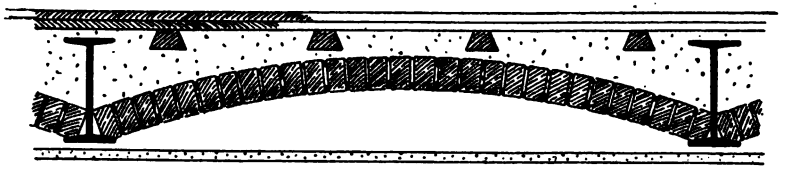


Fig. 231. Section Showing Typical Brick Floor Arch Construction

the columns, the kind of wall and floor construction, and the size and spacing of floor beams and girders must be decided. The location of the columns and girders will be determined by the size and shape of the floors, the position of present or future partitions, the floor loads, and other considerations which arise with different locations and uses.

Original Fireproof Floor. The size and spacing of the floor beams will depend upon the style of floor construction which may be adopted. The original fireproof floor construction consists in spacing beams 5 or 6 feet apart, and turning a brick arch from flange to flange of the beams, Fig. 231. The space above the arch is filled with concrete up to about an inch above the beams, completely enclosing the steel; and screeds, running parallel to the beams and bedded in the concrete, give a sufficient nailing for the floor

boards. The ceiling underneath may be finished by simply plastering on the underside of the brick arch, or a level ceiling may be hung to the rough floor. As an arch of such a shape will exert considerable thrust, this must be taken up by the use of tie rods $\frac{5}{8}$ inch or $\frac{3}{4}$ inch in diameter, spaced along below the center line of beams at intervals of about 6 feet. This style of flooring weighs about 70 pounds to the foot, and has been practically superseded by the lighter constructions employing terra cotta arches or concrete.

Terra Cotta Floor Arches. Hollow terra cotta blocks, molded in the form of a flat arch, are used to a large extent for fireproof floors, and are to be obtained in a variety of patterns and devices. These various patterns may be divided into two principal classes

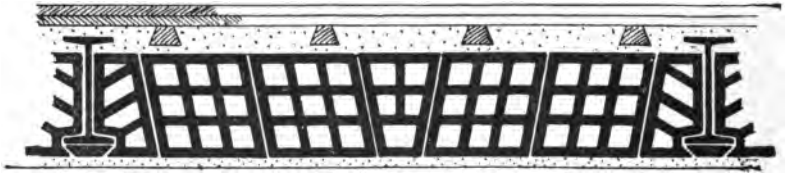


Fig. 232. Section Showing Side Method Terra Cotta Arch Construction

according to the method of laying—the side method and the end method.

Side Method. The side-method arch, where the blocks are laid with the webs parallel to the beams, Fig. 232, is the original form of terra cotta floor arch, while the end-method, where the blocks are laid end to end at right angles to the beams, is an improvement designed to present the full end-section of the material to resist the great thrust of the arches. These side-method arches are usually made of dense terra cotta and may be obtained of various depths from 6 to 15 inches; they should be set with close joints and thoroughly cemented together. Specially molded blocks, called skewbacks, are made to fit the lower flanges of the beams and project about 2 inches below the beam, which is covered by a thin strip of tile. The space above the blocks is filled with a cinder concrete, in which beveled wooden strips are imbedded as a nailing for the wooden floors.

Side-method arches are made to break joints endways, so as to give a bond; and they are usually strong enough for all ordinary floor loads. The joints in the blocks are generally made parallel to

the sides of the key block, as this gives a uniform pattern and so is less expensive than a radial jointing; the latter makes a stronger

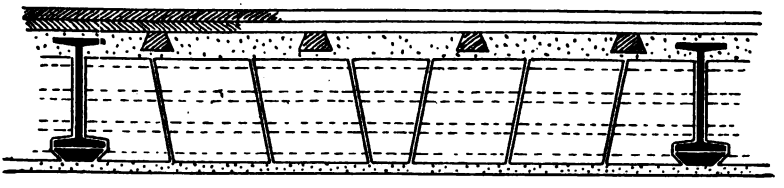


Fig. 233. Section Showing End Method Terra Cotta Arch Construction

arch, but on account of the expense of making and adjusting the different patterns, it is little used.

End Method. In this method, the blocks are usually made of porous terra cotta and are set end to end, giving greater resistance to the thrust by forming a series of continuous webs from beam to beam, Fig. 233. The blocks are generally set in continuous lines, not breaking joints. The jointing of the tiles must be done with great care, as the open ends do not give so good a surface for cementing as do the tiles laid by the side method, and, the bearing on the beams being given by the thin webs, it is necessary that the joints be perfect.

Combination Method. Because of the difficulty in jointing, a combination method is often used, shown in Fig. 234. This gains the extra strength of the end blocks, and the better bearing of the

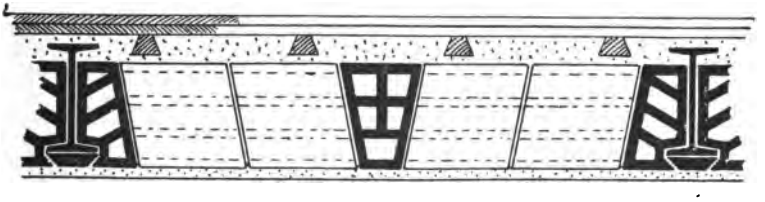


Fig. 234. Section Showing Combination Terra Cotta Arch

flat skewbacks, the skewbacks being made with many webs and of small sections.

Setting. Floor tiles of either pattern must be set upon plank centers which are hung from the beams, and should be crowned $\frac{1}{4}$ inch in an arch of 6 feet. All joints must be close, and made with cement. The centering should be left in place until the cement is thoroughly set, which will require from twelve to thirty-six hours,

according to the weather and the nature of the cement, and care must be taken that the freshly laid tiles are not too heavily loaded

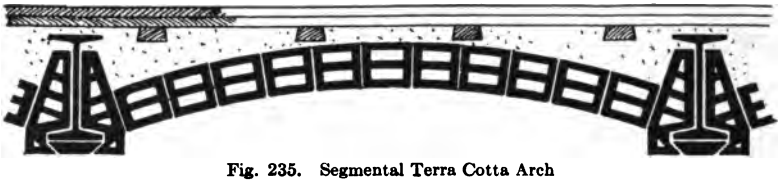


Fig. 235. Segmental Terra Cotta Arch

with materials until they are hard. If the arches are to be plastered upon for a ceiling, they must be kept clean, or bad stains are likely to appear. All holes or irregularities on the underside must be filled with cement mortar to give a proper surface for plastering. Where a flat ceiling is not required, but strength is the main factor to be observed, segmental tile arches are often used, Fig. 235, made with a rise of an inch to the foot, up to 20 feet of span. They are employed to a great extent in warehouse construction.

While the nature of floor tiles does not permit a fine joint to be made, they should be laid as closely as possible, especially the key blocks. Joints as great as a half-inch should not be permitted, and the tiles should be set in place by being shoved together as in brick laying. Unless the building is closed in, floor tiles cannot be laid in cold climates when there is danger of freezing and thawing, as the joints are likely to be affected to the extent of causing deflection, if not more serious trouble.

Floor arches are often tested by applying a heavy roller to them after the wood centers have been removed, and by dropping a heavy block of timber upon the arch, a 2-inch bed of sand being previously spread over the tiles to prevent mechanical damage.

Concrete Floors. The use of concrete for floors has become an important factor in the construction of fireproof buildings. Con-

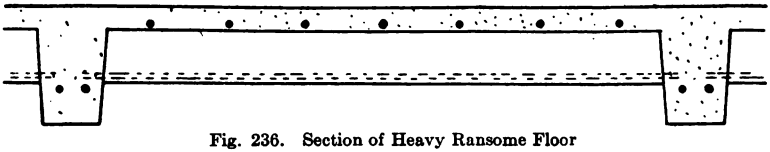


Fig. 236. Section of Heavy Ransome Floor

crete floors combine the qualities of strength and ease of construction with lightness, and are less expensive than most of the hollow-

tile constructions. Concrete so used is generally found in combination with steel or iron in some form or other; it is to the reinforcing material that the concrete owes its tensile strength.

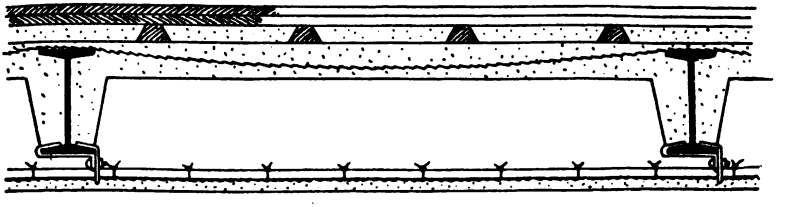


Fig. 237. Section of Expanded Metal Floor

Concrete floors may be considered under two principal classes, one in which the concrete in combination with steel tensile members forms the whole of the floor construction, Fig. 236, and the other in which steel I-beams are set as for brick or tiles, the spaces

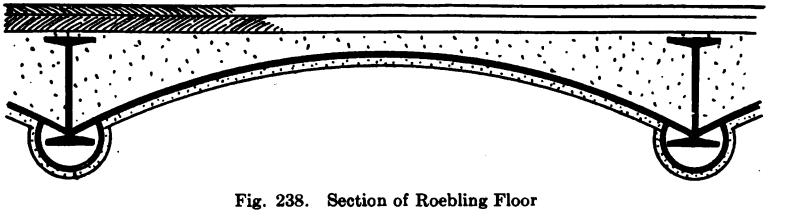


Fig. 238. Section of Roebling Floor

being filled in with concrete, either in the form of a plate, Fig. 237, or supported upon an openwork metal base, Fig. 238.

A newer type, which partakes of the characteristics of either or both of these forms, employs hollow forms of corrugated or perforated steel or of some plaster-holding composition so spaced as to divide the floor into a series of beams or panels made by the concrete filling which is poured between and over the hollow forms as centering, the forms shown in Fig. 239 remaining in place in the finished structure.

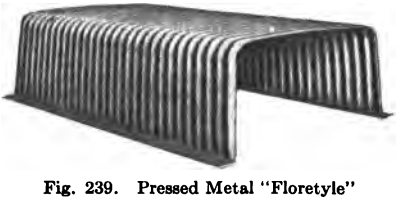


Fig. 239. Pressed Metal "Floretyle"

Various patented forms are used in this way so designed as to be adjustable to any length or width, and so arranged that, by spreading, different widths of beams may be obtained. These forms

are called by various trade names such as "Ferro-Domes", "Flore-Domes", "Floretyles", etc.

Advantages of Different Types. With many types of flooring available, each possessing merits peculiar to its own construction, the architect is often at a loss to decide upon a special system. Cost, which is an ever-present factor, will decide in many cases, and in others local considerations may require particular methods. In the main, regard should be given to lightness, strength, and fire-resisting qualities, as well as to speed of erection and the skill of available workmen.

Of the respective merits of the two general systems of terra cotta and concrete, much has been written, especially with regard to fire-resisting qualities, but the question of the advantage of one over the other cannot be said to have been settled at the present time. For the very high buildings, one of the systems requiring the use of riveted steel floor beams and girders is usually adopted, the beams spaced not only with reference to the load and the requirements of the floor construction, but with a regard to the general strength and stability of the whole building.

Fireproofing. The various parts of a building of steel construction are in themselves of a fire-resisting character, but for the thorough protection of the structure, special devices must be employed.

Fig. 240. Terra Cotta Column Casing

Fig. 241. Lath and Plaster Column Casing

Columns. Especially is this true in the case of columns, which must sustain great weight and should, therefore, be adequately protected. Columns may be enclosed in concrete or brick, which should be not less than 8 inches thick; or hollow terra cotta tiles may be used, preferably in two layers, each not less than 2 inches thick and breaking joints, Fig. 240. Columns may also be partially protected by the use of metal lathing and plaster in one or two layers with an air space between, Fig. 241.

Floors. Floor beams and girders are protected normally by the floor or ceiling construction, and each maker of floor construction has his own system of fireproofing for girders and columns and

other exposed members, so that, in general, the contractor for the floors will be given a contract for all the other fireproofing in the building.

ROOF AND WALL CONSTRUCTION

Roofs and Ceilings. As the roofs of high buildings are generally made with very little pitch, the same construction may be used here as for the floors, but a special treatment will be required to retain a level ceiling in the upper story. This is usually done by hanging steel T-bars at a level below the roof, upon which a ceiling may be laid either of terra cotta blocks to be plastered, Fig. 242, or of metal lathing, Fig. 243.

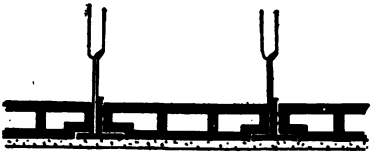


Fig. 242. Hanging of Terra Cotta Ceiling

Exterior Walls. The construction of the exterior skeleton of a fireproof building varies according to the covering material. While the adopted type of floors may be carried throughout one or several buildings, by a simple repetition of methods, the construction of the outside frame must be modified to suit the different materials used in different buildings, or often in different portions of the same building.

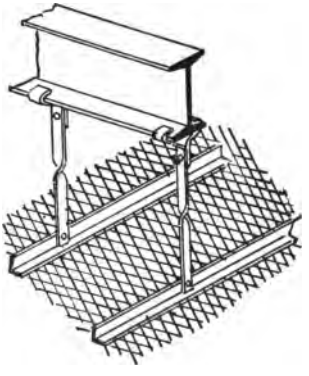


Fig. 243. Hanging of Wire Lath Ceiling

The exterior treatment of a building of skeleton construction may be said, in general, to resolve itself into a series of piers, more or less marked in character, which enclose the vertical supports, the space between them being to a great extent occupied by windows, while a horizontal piece of masonry separates the windows of each story and covers the floors.

The masonry enclosing the building is generally supported by the steel frame, and may be of brick or stone, according to design, though concrete and terra cotta in molded or cast forms are also available.

Terra Cotta Covering. The adaptability of terra cotta to the exterior adornment and fireproofing of buildings is so great that its

use has become general in all places where durability and resistance to heat are essential. The ornamental facings cannot always be supported by direct bearing on the steel frame, and so a system of anchors and ties must be devised by which the separate blocks may be held in place.

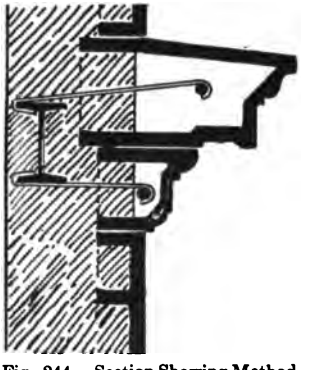


Fig. 244. Section Showing Method of Anchoring Terra Cotta

For terra cotta finish which has no great projection from the line of support, ties of $\frac{1}{4}$-inch rods may be hooked into the ribs of the terra cotta and secured to the steel frame or the brick filling, Fig. 244; but when a greater projection is required, as for cornices, then small beams or T-irons must be used, well built-in or anchored to the main structure, Fig. 245. Exterior terra cotta as ordinarily finished is not affected by the atmospheric conditions which affect stone; but as the surfaces are likely to become warped in the baking, it is necessary to see that no attempt is made to straighten bad pieces by chiseling, as this destroys the surface and exposes the softer interior to the danger of decay.

PARTITIONS

The partitions of fireproof buildings may be built of brick, terra cotta, tiles, or plaster blocks, or of light iron studding with metal lathing and plaster. Brick partitions, to resist the passage of fire, must be at least 12 inches thick, and are not, therefore, generally used unless required for floor bearing also. With the column and girder construction which we have had under consideration, a lighter construction than brick is generally desired for partitions.

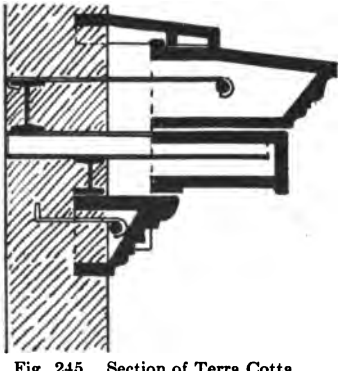


Fig. 245. Section of Terra Cotta Cornice

Partition Blocks. Terra cotta blocks, either of dense or porous terra cotta, make good partitions, Fig. 246; these are usually made 4 inches thick, and are of the same composition as the floor blocks. They are generally set with the hollows

running horizontally, in order to obtain the flat surface for bedding, but where it is necessary to cut for vertical pipes, it is well to set a vertical line of blocks on end and clamp them to the flat tiles. All openings for doors and windows are made with wooden studs (or with steel bars, if the door frames are of cast iron) to receive the frames and finish. For thinner partitions, blocks of solid porous terra cotta 2 inches thick may be used, but they must be clamped or banded together. A patented partition may be obtained of thin terra cotta plates, reinforced by twisted steel wires run on either side of the plates and imbedded in the plaster. Thin plates having plaster of Paris for a base, and clamped or banded with iron, are also used for partition blocks where extra lightness is required.

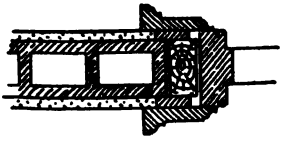


Fig. 246. Terra Cotta Bloc Partition

For all of these blocks, mortar composed of lime with a little cement should be used for setting, and the finished plaster surfaces are best when hard-setting plaster is used.

Metal-Lath Partitions. To save floor space, very thin partitions may be made by using small steel bars for studding; these are usually $\frac{3}{4}$-inch channel bars set vertically about a foot apart and turned at a right angle to be fastened top and bottom. On one side metal lathing is stretched and wired to the bars. This is covered with a very heavy coat of hard plaster, which squeezes through the lathing and makes a good surface to receive the plaster of the other side of the partition, the whole forming, when completed, a solid wall of plaster and metal about $1\frac{1}{2}$ inches thick, Fig. 247. It is necessary in this case to use a very hard-setting plaster, as this gives the partition its stiffness. Special patented studs of sheet steel, made with prongs to hold the lathing, and of various depths, Fig. 248, are used in a similar manner. Door and window frames are placed in these thin partitions by setting up a rough wooden frame to which the channel bar is screwed, as in Fig. 249, and as a nailing for chair rails, picture moldings, and other finish, strips of wood are laced to the lathing, flush with the plastering, before the plaster is applied, Fig. 250.

Fig. 247. Section of Steel and Lath Partition

Metal Lathing. Metal lathing, which is of great importance both for fireproofing, and for the finishing of fireproof buildings, may be obtained in a variety of patterns and devices.

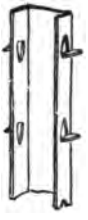


Fig. 248. Steel Stud

Wire Cloth. The original metal lathing was the common wire cloth, and this is still one of the principal forms in which it is found. Improvement in the manufacture of wire cloth has been made by stiffening the cloth in various ways by the use of rods or ribs of metal. These are attached to, or woven into, the lathing which is then known as *stiffened lathing.*

Clinton Lath. A well-known form of stiffened lathing is the Clinton lath, which contains corrugated steel furring strips, attached to the cloth by metal clips and running across the roll every 8 inches. These strips not only serve to stiffen the lathing when stretched over furrings, but, if the lathing is applied directly to a plain surface, such as planking or brick walls, the stiffening keeps the lathing away, and gives room for the clinch of the plaster.

Fig. 249. Door Finish in Thin Partition

Roebling Lath. The Roebling stiffened lathing contains V-shaped ribs of various depth, which are woven into the cloth at $7\frac{1}{2}$-inch intervals. These ribs serve for a furring, and are made from $\frac{3}{8}$ to $1\frac{1}{2}$ inches in depth. For special uses, ribs of $\frac{1}{4}$-inch steel rods are used instead of the V-shaped steel. Wire cloth for lathing is run in a variety of meshes, 3×3 and $2\frac{1}{2}\times2\frac{1}{2}$ to the inch being the common meshes, and they may be obtained plain, painted, or galvanized. Painted lathing is very satisfactory, and is more generally used than any other kind.

Fig. 250. Wood Furring in Thin Partition

Expanded-Metal Lath. This form of lathing is made from strips of thin and tough sheet steel, which are cut at regular intervals and then "expanded" by being wrenched or pushed into open meshes, large or small as the cuts are made long or short. This expanding also turns the metal on edge, making a flat and stiff sheet of lathing much larger than the original piece of metal, Fig. 251. Having a degree of stiffness, this lathing does not require stretching, and it is used extensively for wrapping

steel beams or columns, for fireproofing or finishing, for thin partitions and for concrete floors.

Bostwick Sheet-Metal Lathing. An objection is sometimes made to wire or expanded-metal laths, because they require an excessive amount of plaster for ordinary uses. This may be overcome by the use, when feasible, of the Bostwick sheet-metal lath, shown in Fig. 252, which is made from sheet steel by punching out loops at regular intervals. In this, and in many other forms of sheet-metal lathing, the surface is corrugated, besides being punched, to give stiffness and to keep the lathing away from the surface to which it is applied. Sheet-metal lathing is especially adapted to the forming of coves or round corners, but for fireproofing, the open lathing, requiring a greater amount of plaster with the metal more thoroughly imbedded, is to be preferred.

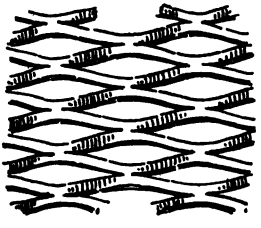


Fig. 251. Expanded Metal Lathing

Rib-Stiffened Lathing. Almost all manufacturers of expanded-metal lathing make some form of lath having ribs or stiffeners of different depths, some only enough to give a clinch to the plaster, others deep and stiff enough to give an amount of strength such that the material may be used for a light roof or partition without the usual joists or studding.

This method of stiffening or furring is more valuable to expanded or sheet-metal lathing than to wire lathing, inasmuch as it can be formed up integral with the lath, this producing great stiffness, if desired. This material is known to the trade as "Hy-rib", "Self-Sentering", "Corr-Mesh", or by some other title more or less descriptive of the product.

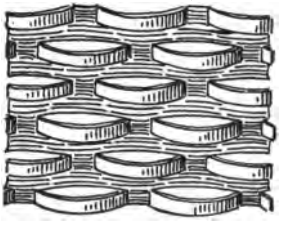


Fig. 252. Bostwick Lath

HEATING, LIGHTING, AND PLUMBING

The running of pipes and conduits in fireproof buildings brings forward a system differing in some essentials from the ordinary piping of buildings with wooden floors. In the first place, less cutting of material is possible to make spaces for pipes, and so more careful

consideration must be given to their placing in the early stages of the construction; and, again, the necessity of leaving no continuous channel or connection from one floor to another, which would allow the passage of fire, requires that the pipes be run in exposed situations so far as possible, so that the floor material may be filled closely around each pipe. This is a point that the superintendent will need to keep constantly in mind and be sure that it is done in every case.

Plumbing Pipes. The main soil, waste, and vent pipes should be of wrought iron with screw joints, not only on account of the great weight of the high stacks of pipes, but also because the expansion and contraction of the great height of pipe would destroy the lead calking usual with cast-iron pipes. The pipes must be securely fastened to the solid frame of the building, and all joints well screwed together with ample allowance for expansion. Brass supply pipes should be used throughout, nickeled or bronzed to taste when showing. As the pipes will all show, the soil and waste pipes need to be smooth and well put together so that when bronzed or finished they will not be unsightly.

Gas Pipes and Electric Conduits. Before the plastering is begun, the pipes for gas and the conduits for electric wires must be run. These, being small, may be concealed, although the idea of exposing gas piping is coming more into vogue, especially where thin partitions are used. When the partitions are made of hollow blocks, it is customary to channel them so that the rising pipes and conduits may easily be carried through; while the horizontal pipes are usually bedded in the concrete filling over the floor construction, Fig. 253.

There are some types of construction where the horizontal pipes are run under the floor beams, the suspended ceiling being dropped low enough to allow free circulation for the pipes. Sometimes the pipes are run between the floor beams; but if the girders are framed flush, it will be necessary to punch holes in them, and lateral branches cannot be easily managed. Where no partitions are available in which to run vertical pipes, as often occurs in the lower stories, the casing of the steel columns may be enlarged, to allow for the pipes; but if this is done, a separate flue outside the column casing, as in Fig. 254, should be made, since the insertion of

pipes or conduits directly into the column casing destroys its fireproof value to a large extent, besides subjecting the steel to the action of injurious gases.

Fig. 253. Electric Outlet in Terra Cotta Ceiling

Heating Pipes. The pipes for heating the building, are, as a rule, run outside of the plaster, and are bronzed to match the radiators and other exposed piping. The number and size of the pipes depend upon the system of heating used. For a large building, the heating is generally put in charge of an engineer who devises a system subject to the approval of the architect, but some stated conditions will in general be found to apply to most buildings.

Heating System. In almost every large building, the exhaust steam from the engines necessary to run elevators and dynamos suffices to heat the rooms, and this heat may be made available in either one of two ways. The exhaust steam may be forced or drawn through the radiators so that it transmits heat directly to the building; or it may be carried to a coil in a water tank in the basement where it will heat the water, causing it to circulate through the pipes and radiators instead of the steam. By the latter method a more nearly uniform distribution of heat is obtained, and any danger of back pressure on the engines is avoided. It is important to see that the tank is placed low enough to prevent any backing-up of the water to the engine.

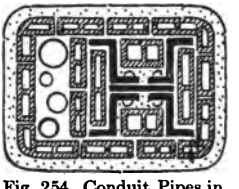


Fig. 254. Conduit Pipes in Column Casing

The circulation of hot water to the radiators may be laid out in a manner similar to the circulation from an ordinary heater, which has been previously described. The greater height and multiplication of radiators require a much more complicated system of piping, but the main features are the same. The most effective service is, of course, obtained by putting as few radiators as possible on a direct circulation, but, as this adds very much to the expense, it is quite usual to run one or two large mains up to the top floor, and from a horizontal run in this story to bring down the hot water to supply the radiators, the pipe being continued to the heater.

This of course gives a better supply to the top stories than the lower ones, and the difference is made up by making the lower radiators larger. The first story, exposed to the cold from big windows and doors, is sometimes supplied directly from the risers, and the discharge returned by separate pipes to the tank, while the other radiators, being supplied by a descending current, receive the steam from the same pipe into which it is discharged without interfering with the circulation.

The system of indirect steam heating by means of a fan is often to be preferred for the large stores or corporation offices, which usually occupy the lower story of a city block. For the heating of the smaller upper offices, it is a good plan to drop a riser, as described, between each pair of windows, a small radiator being placed in front of every window. These may be supplied with fresh air by means of sash ventilators or other fresh-air inlets, or they may warm the room by direct radiation.

Lavatories. The plumbing fixtures of an office building need not differ to a great extent from house fittings, and the same principles of construction apply. The fixtures consist mainly of bowls, or sinks, and water closets and urinals. All fittings should be strong and of simple construction, easily accessible for repairs or cleaning. The use of wood for partitions or floors should be avoided when possible, marble slabs and marble, mosaic, or tile floors being preferable. Water closets need to be placed in well-ventilated ranges, with partitions of marble or other impervious material, and slatted doors kept up a foot from the floor. All hinges, fastenings, and metal fixtures should be of nickel-plated brass. Urinals of the ventilated-hood pattern are to be preferred and these should have a dished floor slab of ample dimension.

Structural Glass. As an improvement on marble for toilet partitions, opaque glass is often used. This has the quality of being entirely nonabsorbent and unstainable, remaining permanently clean and sanitary. The glass can be obtained in slabs up to 6 or 7 feet in width, and 9 or 10 feet in length, and of a thickness suitable to the purpose required. For dadoes or other slabs which are applied to a backing, $\frac{7}{16}$-inch or $\frac{1}{2}$-inch slabs may be used; when standing free, as for partitions, the slabs should be $\frac{3}{4}$ or 1 inch in thickness and polished both sides. For toilet rooms a high polish

is desirable as this is more sanitary and presents a surface upon which it is impossible to write.

Caps and base members, coves, and tile shapes can be obtained to set against a cement backing in the same manner as ordinary tiling. This form of structural glass is known to the trade as "Carrara", "Opalite", or some other name suggestive of its particular quality or appearance.

FINAL BUILDING OPERATIONS

Plaster. The use of the so-called "hard plaster" for the finishing of business and public buildings is to be advised wherever the slight increase in expense can be borne. For business blocks the saving in time will usually more than cover the extra cost, and for schools and hospitals the harder and cleaner surface is very desirable. These plasters are made, some of natural cement and others by chemical preparation, and when dry they form a clean, hard surface.

Natural Cement Plaster. The natural cement plaster is slower in setting, but of great adhesiveness, while the chemical or patented plasters set very quickly and give good results when properly used. The cement plasters are sold as a cement only, and the sand is applied when the mortar is mixed. For use on lathing, "fibered cement" should be obtained, but for plastering on brickwork or terra cotta, cement without fiber may be used. These cements are known as "Acme", "Agatite", and "Royal Cement".

Chemically Prepared Plaster. The best known of the chemically prepared plasters are "King's Windsor", "Adamant", and "Rock" plaster. These are sold with the fiber and sand all combined and ready to use after being mixed with water in the prescribed proportion. Full instructions for use are furnished by the manufacturers, and these directions should be followed absolutely, as they are the result of careful preparation and long experience. The plasters can be finished with a white coat as upon lime mortar, and this will be necessary if a white finish is desired upon the natural cement plasters, which are themselves gray in color.

Plaster for Bases, Dadoes, Columns. For a very hard finish for bases, dadoes, columns, etc., or for any plaster work where a polish is required, Keene's cement, an English preparation, is generally

used; but some of the best grades of American manufacture are said to be as hard and less expensive than the imported cement. Keene's cement is sold in two grades, coarse and superfine, either of which will make a hard finish, but superfine must be used to secure a polish.

Scagliola. For interior finish on columns, dadoes, etc., scagliola, or imitation marble, is used to some extent. This is made upon a ground of lime mortar containing a large proportion of lime and hair. When this groundwork is thoroughly dry, it is covered with a coat of Keene's cement on plaster of Paris, which is mixed with the various colors and polished until it resembles marble. For flat surfaces, this is sometimes made in slabs upon plate glass. Silk threads, dipped in a thin solution of plaster of Paris, colored to imitate the veining, are arranged upon the glass, and the body color put on over them. The silk threads are then withdrawn, and a backing of plaster of Paris and cement, with a webbing of canvas, is spread to the desired thickness. The slabs, when hard and dry, may be taken from the glass and polished in the same manner as genuine marble. When scagliola is skilfully made and polished, its resemblance to genuine marble is almost perfect.

Window Frames and Windows. It has been the custom to make the window frames and sashes of a fireproof building of wood, in the same manner as the frames in ordinary city buildings, shutters of tinned wood or metal construction being depended on for protection against outside fires. Later developments in fireproof construction, and the disastrous effects of fires in the vicinity of many so-called fireproof buildings, have led to the growing use of metal for all external parts. Several patented forms of metal frames and sashes have been introduced, among which are some made of wood and covered with metal, as shown in Fig. 255, and others entirely of metal, Fig. 256.

The windows are arranged to close automatically, and, when glazed with wire glass or with small lights of prismatic glass in metal bars, form a filling which is acceptable to most of the insurance exchanges. This style of glazing is, of course, not adapted to show windows and large store lights, but as the upper stories, in which it can be used, are subjected to the greater danger from fire in adjoining buildings, this defect does not mar its usefulness.

Doors and Other Inside Finish. While wood is still employed to some extent for the inside finish of fireproof buildings, the use of incombustible material is increasing. The forms of metal-sash construction which we have described for outside windows can all be adapted to interior uses, and, with metal doors and frames, and marble or mosaic floors, each office made practically fireproof in itself. Doors with sheet-metal coverings are often used, either plain or molded to resemble wooden doors, and they may be set in cast-iron frames made with rebates or channels to receive the plaster or block partitions, Fig. 257. These doors are made of hollow metal with a wooden or composition core completely encased in sheet metal, Fig. 258.

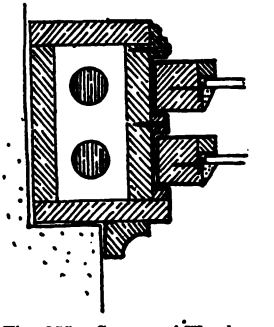


Fig. 255. Section of Wood-Covered Fireproof Window

Influence of Insurance Rates. This use of metal for doors and for other finish has been stimulated by the requirements of the National Board of Fire Underwriters. In order to obtain the lowest possible insurance rates, it is necessary to install fittings which are approved by this body, and in the manner required by them; consequently, when doors or windows of this nature are specified for certain localities, it is not necessary to state the quality of the material or the construction, but only the desired appearance and finish when completed, as the door or window must be exactly in accordance with the sample which has been approved by the underwriters for each individual manufacture. For instance, in order to procure a "Standard" door, it is not necessary to give any other specifications than that "the door shall be Standard, and bear the labels of the Underwriters' Laboratories".

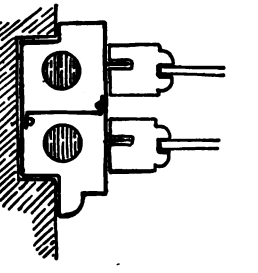


Fig. 256. Section of Fireproof Window Entirely of Metal

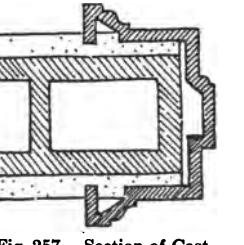


Fig. 257. Section of Cast Iron Door Jam

In non-fireproof buildings or semi-fireproof buildings, the insur-

ance requirements are not so strict, and the safety of this type of building is usually guarded by local or municipal laws.

Sliding Doors. When sliding doors are to be used, especial care must be taken to select a good hanger, which will give the essentials of freedom from noise, ease of motion and adjustment, as well as durability.

For ease of running, a ball-bearing hanger is best, and for noiselessness a type in which the wheel runs on a wooden track is essential. For sliding doors in residences, a single line of track will usually suffice, but for schools, classrooms, and elevator enclosures, runs of parallel tracks with trolleys of different speeds are often required. Accordion or folding partitions are required in many classrooms and auditoriums, and when these are installed, swivel hangers become a necessity. The remaining hardware for sliding doors consists chiefly of recessed cup handles and a special lock and key.

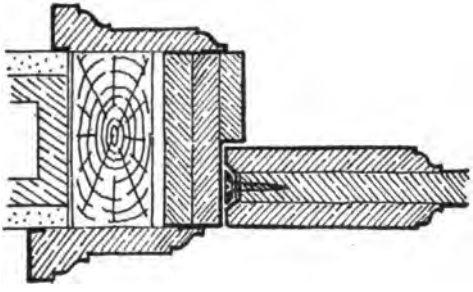


Fig. 258. Section of Sheet Metal Door and Finish

Stairs. As the stairs of a high building are rarely used above the first stories, except for emergency, or at times when the elevators are not running, it is the custom to make staircases simple in design and construction, except perhaps the lower flights, which are often of marble or ornamental iron or steel. A simple form of stair construction, and one in general use, consists of a plain cast-iron riser and marble or mosaic treads, Fig. 259.. The outside stringer may be more or less ornamental, and the soffit or underside of the flight should be neat and presentable, as it will be in close view when passing down the flight underneath. The stairs should be arranged so that the stringers will not be too long to be of cast iron, if desired; but sometimes a steel beam or channel is used with the forming for the steps bolted on, Fig. 260. Whether the cast-iron or steel stringer is used, the bottom and top of the stringers must be securely fastened to the floor beams.

Sometimes the stairs are laid out to enclose one or more elevators

in the well room, and in this case a support for the stringers can be obtained by the corner posts of the elevator enclosure, which, in turn, will be strengthened by the lateral support of the stairs.

Painting. With the hanging of the doors and the setting of the hardware, the mechanical processes will be completed, and the building will be turned over to the painters for finishing.

The methods and materials differ little from ordinary painting, varying mainly in the smaller amount of woodwork and the greater amount of finished metal and plaster work to be treated. All iron

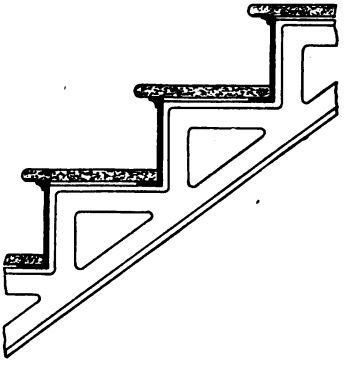


Fig. 259. Cast-Iron Stair Stringer and Finish

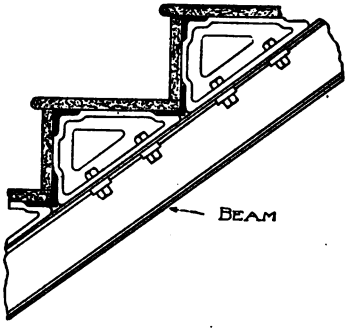


Fig. 260. Beam Stair Stringer and Finish

or steel work which is to be painted must be perfectly clean and free from rust or moisture. Rust spots can be removed by scraping or burning. The paint on fine ornamental work must be carefully applied in thin coats so as not to obscure the pattern. Plaster which is to be painted must be free from flaws or cracks, and both plaster and wall behind it must be thoroughly dry. Plastered walls should be brushed over just before painting, and the surface sized or primed.

FINAL INSPECTION

With the departure of the painters, it remains only to see that the building is thoroughly cleaned from top to bottom, and that all paint spots have been removed from glass, marble, and all other exposed material.

The superintendent should carefully review all notes and memoranda made during the progress of the work, and be prepared

to furnish a complete and detailed account of proceedings, including a record of all orders received and given, materials rejected, and the defects which warranted their rejection.

A diary should be kept, recording the state of the weather, the number of men of the different trades employed, the progress from day to day, a record of accidents, and any other data which would be likely to prove of value or interest. A record of this sort may not only be of use to the owner, but will contain data which may be of great value to the superintendent as a guide for future operations.

UNDERWRITERS' LABORATORIES, CHICAGO

UNDERWRITERS' REQUIREMENTS

PART I

INTRODUCTION

The insurance interests are concerned with electric work only for the reason that such work if done improperly constitutes a fire hazard, and underwriters' rules on electrical installations are, therefore, confined to such questions as concern proper methods and materials to be employed to minimize the chance of fire arising from the use of electricity for light, heat, and power. Electricity as employed for signaling work, such as telegraphs, telephones, call bells, burglar alarms, and similar purposes, is not covered by insurance rules except in so far as such installations may become dangerous because of the liability of wires in such systems becoming crossed with electric light, heat, or power circuits.

The many applications of electricity for municipal fire-alarm systems, factory or isolated plant fire alarms, watchman's time-recording appliances, and automatic alarms employing electric thermostats, are not covered by the general rules for electric work. They do not in general tend to cause a fire hazard of themselves but come rather under the head of protective devices and the discussion of them does not, therefore, come within the scope of this paper.

The earlier installations of electrical lighting and power appliances were very crude and were often made with no consideration of what are now generally admitted to be questions of great importance from the viewpoint of fire protection. It was natural that experience should have been necessary to demonstrate the need of protection against unreliable or hazardous methods of applying electricity and to develop improved materials and devices. The comparatively mysterious nature of electricity as viewed by the general public led at first to a habit, not yet wholly outgrown,

of attributing to electrical causes all fires for which no other cause was readily apparent. Today, however, the production of light and the transmission of power are without question accomplished more safely as well as more conveniently and economically by electricity than by any other means.

In judging electrical work as affecting the fire hazard, the fire-protection engineer and underwriters cannot undertake to do for the assured, the work which lies within the province of the electrical engineer on whom properly falls the responsibility of designing installations and choosing the methods and materials to be used to accomplish the results desired. In electrical, as in other engineering, considerations of first cost, economy of operation and maintenance, efficiency of machinery and appliances, depreciation, and reliability are of prime importance. It is the proper function of the fire-protection engineer to act as critic of the plans and their execution in order that other considerations involved shall not be allowed to dictate methods which do not afford suitable and reasonably safe fire conditions. Electrical engineering is far too complicated a profession to be fully mastered by the fire-protection engineer or by an inspector, but the general principles of safe electrical work can be mastered and applied without presuming to encroach on the work of either the consulting or the installing engineers.

Architects are now very generally prepared to recognize the necessity of providing in their plans for the electrical installations which in more elaborate buildings must be given very careful attention if adequate provision is to be made for electric wires and appliances. It is in the smaller and less carefully planned structures that the electric work is most likely to be left to the installers to be put in as best it may. A well considered plan adapted to the type of building and the uses to be made of current is an essential to successful and safe work. Makeshifts are usually dangerous. For this reason, also, it is often much more difficult to secure proper electrical work in wiring old buildings than new ones.

Electrical contractors are usually willing to do good work for a fair price and most poor work is due to an attempt to secure business at too low rates in order to meet competition. Since a faulty or dangerous electrical installation may perform its appointed work, and since electrical defects are not easily discovered, often develop-

ing after some time, only thoroughly good work from the start affords real protection against disastrous failure from causes which, after a fire, may be very difficult to assign but which might have been easily foreseen and removed.

Electrical inspectors either of the underwriters or of the municipality should be fully acquainted with approved methods, rules, reasons for rules, and must have a great range of practical knowledge which only actual field experience can give; and such inspectors must be specialists of a high order. The fire-protection engineer must refer to such specialists the technical details while undertaking himself to be a competent judge of general methods and principles.

Electricity as a Cause of Fires. Electricity may in general be the cause of a fire in either one or both of the following ways:

First: By causing wires, cables or other conductors to be overheated by the passage of the "electric current," thereby setting fire to the insulations on such conductors or to nearby combustible materials. All conductors are heated by any current however small, but if the conductor is badly overloaded it may become red- or even white-hot. Hence it becomes necessary to prescribe the safe carrying-capacity of wires, and all conducting parts of electric appliances must be properly proportioned. Such parts as are peculiarly liable to become heated or which must be heated to perform their proper function must be suitably protected and separated under all circumstances from materials which might be ignited.

Fuses, circuit breakers, and other automatic appliances have to be installed to afford protection in case of accidents which may result in conductors or other devices being overheated by abnormally large currents. Such protective devices may themselves become dangerous and the rules, therefore, prescribe carefully how they must be constructed and installed. Overheating of conductors is thus one of the two general ways in which electricity may cause a fire and provisions against such accidents, therefore, form an important part of the rules.

Second: Electricity may form "arcs." An arc is the visible evidence that the current is passing from one conductor to another or across a break or gap through the air or over the surface of an insulating material. An arc always causes heat and if any appreciable current passes, the arc will be very hot and if continued is capable

of melting the adjacent metal at the gap or setting fire to any combustible matter near by. It, therefore, becomes necessary to prescribe rules, the observance of which tends to lessen the chance of accidental arcs being established, and to so locate all appliances, the operation of which produces arcs, that no harm will result. Switches, circuit breakers, and fuses are all "arcing" devices. The problem of insulation, spacing between conductors and excellence in materials, methods of installation and workmanship, all have to do chiefly with the prevention of accidental or dangerous arcs.

From the viewpoint of fire hazard, it is well to treat all conductors, however well insulated, as bare, and to proceed to furnish adequate protection against grounds or short-circuits on that basis.

In judging of installations it must constantly be kept in mind that conditions are liable to become worse rather than better after the wiring and appliances have been in use for some time. Requirements are, therefore, made to anticipate in part such deterioration as is inevitable in even the best equipments, and which may be surprisingly rapid when inferior materials are put in by careless workmen and used and abused by those having little or no understanding of electrical affairs and no appreciation of the hazards involved.

The following are the chief general requisites for a safe electrical installation: Excellence of material; simplicity in design so far as compatible with the results to be secured; ease of inspection and repairs of all wiring and appliances; thoroughly good mechanical execution of the work; the choice wherever possible of the more protected and safer forms of wiring; and the use of "approved fittings." No rules can take the place of good designing nor will perfunctory obedience of rules make a poorly executed job, safe. The architect, the owner, the manufacturer of devices and materials, the electrical contractor, the electricians who install and those who operate the plant—each and all must share the responsibility with the insurance and the municipal inspector.

Elementary Electrical Ideas and Terms. Electric power may be transmitted by either direct or alternating current.

Direct Current. Direct current is current of such character that what is usually called the "direction" of the current is always the same, or, more exactly, the magnetic effects of the current are not being reversed from instant to instant. If a small compass be

held near a wire carrying direct current, the needle may be caused to turn away from its natural north and south line. Thus in Fig. 1, if *D* is a direct-current generator connected to a wire from south to north, a compass needle over the wire, before the switch *T* is closed, will point along the wire; when the switch is closed, if current flows as shown by the small arrows on the wire, the needle will turn as shown. The amount it will turn is an indication of the amount of current, but the needle will remain stationary in its new position if the current is direct current. A battery gives direct current and so does a direct-current generator.

Alternating Current. If, however, the current came from an alternating-current generator or from a transformer supplied by such a generator, the needle would tend to swing very rapidly first to one side of the wire, and then to the other. This would also be the case if the connections on the direct-current machine, Fig. 1, were rapidly exchanged back and forth. Such reversals of current direction are made automatically by an alternating-current generator. The number of changes per second is called the frequency and 25, 60, and 135 are the commonest commercial frequencies of alternators. Evidently no compass needle could actually vibrate so fast, but it *tends* to do so, and the result is that the needle does not appear to be affected by the alternating current.

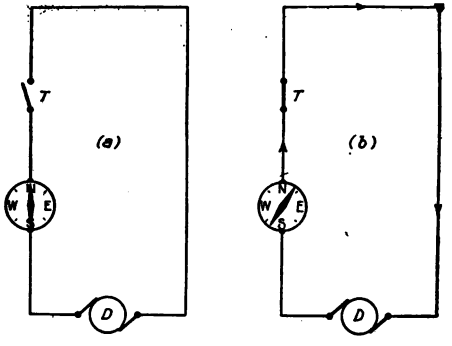


Fig. 1. Diagram of Simple Generator Circuit Showing Effect on Magnetic Needles

Both direct- and alternating-current systems are in common use for light and power. Street railways use at present chiefly direct-current systems. Where power must be conveyed to considerable distances, alternating current is used because it is more economical under these conditions. Different motors and somewhat different arc lamps are required for direct and for alternating circuits. Incandescent lamps are the same for either system as are also most heating devices. Transformers can be used only on alternating-current systems.

The distinction between direct and alternating current is not one which has many important consequences in the safeguarding of electrical work. There are, however, a few important cases where different rules are established. It should be remembered that direct and alternating currents of the same strength produce the same heating effect in a given conductor. In some cases, however, with alternating currents an additional heat effect is produced in certain appliances by the magnetic action of iron cores, of coils, or other parts of the apparatus. In general, alternating current produces less severe and persistent arcs than direct current of the same strength and voltage. Furthermore, alternating-current motors in particular are somewhat less liable to emit sparks and, therefore, have a certain advantage. As a whole, however, no distinction may be made as regards fire hazard between direct- and alternating-current installations which should be made with the same care in workmanship and with the same precautions as to insulations, fuses, and all protective devices.

Current. Current is measured in *amperes.* It may be compared to the number of "gallons per minute" carried by a water pipe through which a stream is flowing. More "current" will, other conditions being equal, do more work, and will always cause more heat in the conducting wires and cables and in the appliances, lamps, heaters, resistances, motors and the like which use the current. Furthermore, the heating effect in conductors such as metals varies with "the square of the current," *i. e.*, if one unit of current produces a certain amount of heat in a wire, *twice* as much current will cause *four* times as much heat in the same wire, *three* times the current will cause *nine* times the heat and so on. An instrument for measuring current is called an ammeter.

NOTE. The heat liberated is a measure of energy or power consumed in the wire. The *temperature* of the wire will not necessarily follow the rule given above, this being dependent not only upon the heat developed but also upon the surroundings of the wire as affecting the readiness with which the heat may be radiated or otherwise gotten rid of.

Voltage. Voltage or potential is measured in volts. *Volts* measure the propulsive force which causes "current" to flow through a conductor. It may be thought of as an electric pressure produced by the dynamo, battery, or other generator of electricity. Through

a given circuit a higher voltage will in general cause a proportionally greater current. Since it is the voltage which may cause electricity to pass from its proper path and seek other and perhaps dangerous paths, higher voltages require better insulation on wires and in all electrical appliances. The voltage used thus becomes an important factor in determining the protection necessary for safety.

Difference of Potential. Two points, as on conductors or between a conductor and the earth, are said to be at *different potentials.* When such an electrical condition exists on them a current *tends* to pass between them either along the conductor or across a gap between the points. Along the conductor such a current produces heat, while if the current "jumps the gap" or *arcs,* heat is produced in the spark or arc formed.

Resistance. Resistance is measured in *ohms.* All substances offer resistance to the passage of current. This is true of metals, liquids, and gases. A good conductor, such as copper, has comparatively little resistance. Other materials, such as slate, porcelain, and rubber, are very poor conductors and may generally be considered as *insulators.* Since heat is always produced, the conductors must be of suitable size and material to keep the temperatures below the dangerous values, or, in cases where the heat is the result desired, suitable protection must be provided. The resistance of conductors is thus a necessary but undesirable property in some ways and a usable and valuable property in others. In all cases the fact that current produces heat in conductors must be reckoned with in electrical problems.

The loss of power from the heat expended in a supply wire is an illustration of the undesired property of resistance. The electric flatiron is an appliance where the resistance produces a useful result.

Ohm's Law. For our purpose here the relation between current, voltage, and resistance in a direct-current circuit may be stated as follows: The current (amperes) in a circuit equals the voltage (volts) divided by the resistance (ohms), or $I=\frac{E}{R}$. This is true both of entire circuits and parts of circuits, provided E and R are the voltage and resistance of the whole circuit or the part under consideration, respectively. For a. c. circuits a somewhat more elaborate formula must be used.

Power. Power is measured in *watts.* (A kilowatt is 1,000 watts.) In direct-current circuits the power expended in any portion of the circuit is obtained by multiplying the current in amperes by the

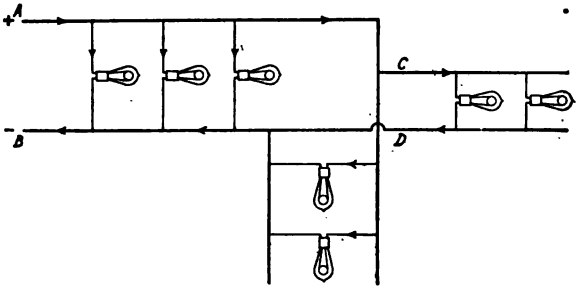


Fig. 2. Multiple Lamp Circuits

voltage across the portion of the circuit. Thus: If the current in an incandescent lamp is ½ ampere and if a voltmeter shows that the voltage across the lamp terminals is 110 volts, the power is 55 watts.

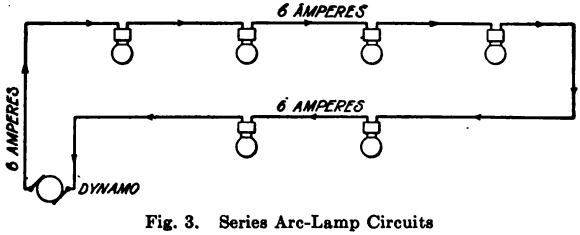


Fig. 3. Series Arc-Lamp Circuits

The corresponding mechanical term is horse-power; 1 horse-power is equivalent to 746 watts and 1 kilowatt equals about 1⅓ horse-power. With alternating current the power in watts is not always

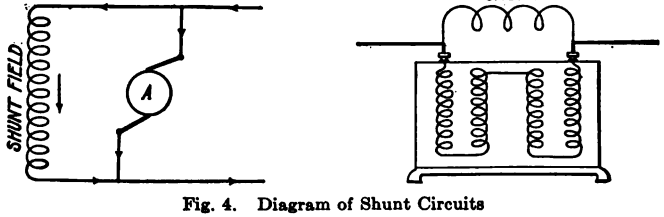


Fig. 4. Diagram of Shunt Circuits

to be obtained by multiplying amperes by volts. With alternating currents, a third factor must be used, called the "power factor" of

the circuit. It is sufficient for our purpose here to remember that the power actually delivered and used with alternating current *may be less* than the simple product of amperes and volts. Thus,

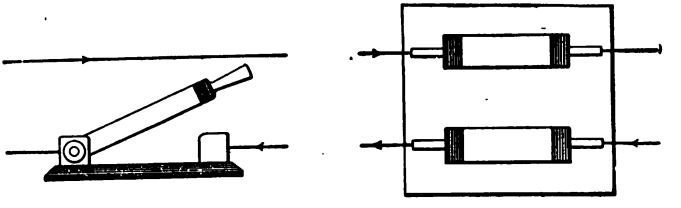


Fig. 5. Single-Pole Switch and Double-Pole Fuses

if a current of 50 amperes as read by an ammeter, passes through a coil of wire, and the voltage across the terminals of the coil is 100 volts, the power consumed, if the current is direct, is $50 \times 100 = 5{,}000$ watts or 5 kilowatts. If, however, the coil surrounds an iron core (as in an electromagnet) and alternating current is used, the power consumed will not be 5 kilowatts. The power factor may be 60 per cent for this coil, and the power consumed will then be $50 \times 100 \times .60 = 3{,}000$ watts or 3 kilowatts, instead of 5 kilowatts. The following definitions will be useful to those unfamiliar with electrical terms.

Multiple Connection. When a number of devices such as lamps, motors, etc., are so connected that the current has a path through

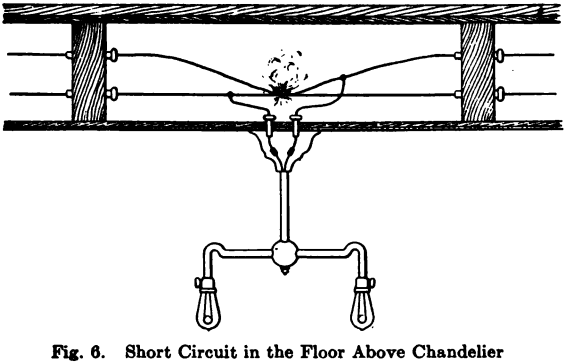


Fig. 6. Short Circuit in the Floor Above Chandelier

each device separately from one supply wire to another, they are said to be connected in *multiple.* See Fig. 2. Incandescent lamps are almost always connected in multiple. In Fig. 2 if each of the 7 lamps shown takes 1 ampere of current the total current at *A*

and at *B* will be 7 amperes, while at *C* and at *D* it will be 2 amperes.

Series Connection. When a number of devices are so connected that they come one after another, they are said to be connected "in series." In Fig. 3, the arc lamps are shown so connected. In this case the same current traverses all parts of the circuit and the

Fig. 7. Effects of a Short-Circuit in Wires Under Floor

total current is no more and no less than the current in each connected series device.

Shunt. A shunt is a by-path between two points so connected that part of the current will traverse it. The division of the total current between the main path and the shunt will depend on the comparative resistances, the larger current going by the path of lower resistance. In Fig. 4 are shown the connections of a "shunt motor" and resistance box "shunted" by a wire.

Cut-Out. A cut-out is a device for automatically breaking a circuit, usually when the current reaches a predetermined value. Thus, a 60-ampere fuse is a cut-out designed to burn out when currents in excess of 60 amperes pass through it. A circuit breaker is an electro-mechanical switch which is also used as a cut-out.

Switches, fuses and other appliances are said to be *single-pole* if they are for but one wire of a circuit; *double-pole* if for two, *triple-pole* if for three. Fig. 5 shows a single-pole switch and a double-pole fuse.

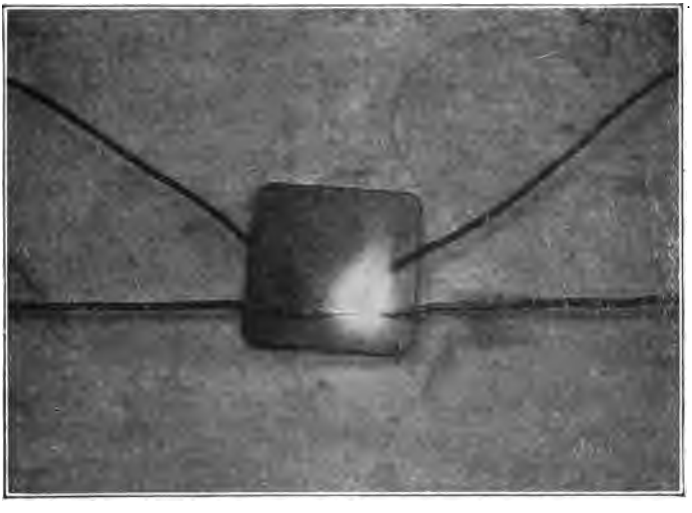


Fig. 8. Arc Between Wires of 250-Volt Circuit

Ground. A ground is a connection either intentional or accidental between a part of an electric circuit and the earth, or any metal or other conducting substances which are in electrical connection with the earth, such as water and gas pipes, iron beams, etc.

Short-Circuit. A short-circuit is a connection which permits current to flow from one part of a circuit to another by any path which it is not intended it should take. Since such a connection is the result of accident or the failure of some insulation, and since it usually allows excessive currents to flow, a short-circuit may be very dangerous and liable to cause a fire, especially as the accidental connection may afford very poor contact and cause arcing and burning at the junction of the conductors. Fig. 6 illustrates a short-circuit in a floor between the two supply wires to a chandelier in-

stalled on the ceiling below. The effect of this short-circuit is shown in Fig. 7. Fig. 8 is from a photograph of an arc produced by a 250-

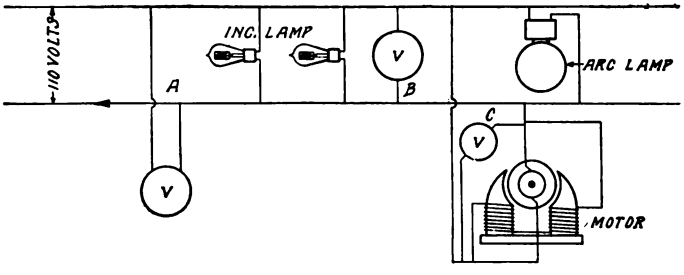


Fig. 9. Diagram of a Constant-Potential System

volt, 10 ampere current between two wires which were touched together at a point where the insulation had been destroyed.

Constant-Potential System. A constant-potential system is one in which the voltage between the main supply wires is approximately the same at all points. Such a system is supplied by a constant-

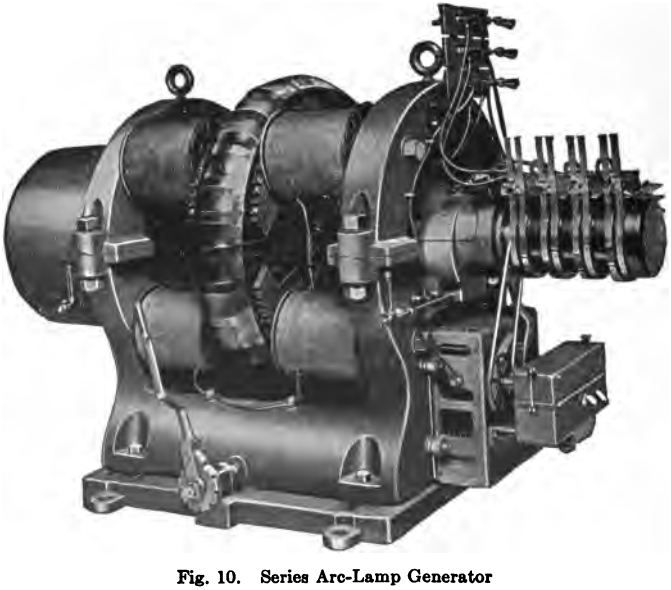


Fig. 10. Series Arc-Lamp Generator

potential generator, which is of a character to furnish greater current as more devices, lamps, motors, etc., are put into use. Most in-

candescent-lamp, motor- and street-railway circuits are of this type and also many arc-lamp circuits. Fig. 9 shows such a 110-volt system and if the distributing wires are properly chosen the voltmeters at the points *A*, *B* and *C* will all read approximately 110 volts. Devices on such currents are connected in multiple.

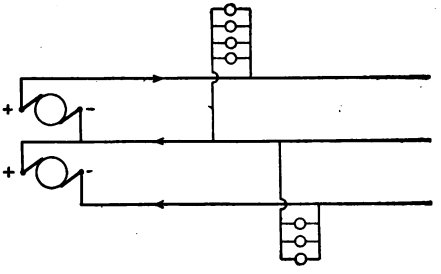


Fig. 11. Diagram of a Three-Wire Circuit

Constant-Current System. A constant-current system is one in which the current is automatically maintained approximately the same regardless of the number and character of the power-consuming devices in use on the circuit. Devices, usually arc lamps, are connected in series and the generator is of a type which automatically increases the voltage or electric pressure as more lamps are turned on. Fig. 3 shows such a circuit and Fig. 10 is a picture of a generator used for series arc-lamp work.

Two-Wire System. A two-wire system is one having a single pair of distributing wires.

Three-Wire System. A three-wire system is a special form of a multiple system usually employing two generators. Fig. 11 shows such a system with two-wire branches to incandescent lamps.

Transformers. The chief advantage of alternating over direct current lies in the fact that electric power can by alternating

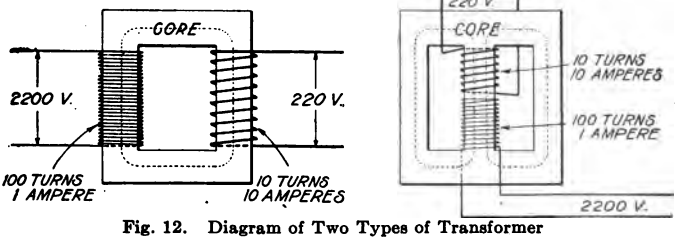


Fig. 12. Diagram of Two Types of Transformer

current be transmitted at a *high voltage* from the generating station to the point where the power is to be used, and there *transformed* with small loss to a voltage better suited to motors and lamps.

It is far more economical to transmit power at high voltages. It can be shown by electrical theory that by using twice as high

voltage, a wire only one-fourth as large is needed to transmit a given amount of power with the same percentage of loss on the transmission line. It should be remembered that if the voltage is doubled the current need be only half as great in order to have the power delivered the same. But half as much current heats the wire which carries it only one-quarter as much and, since the heat dissipated on the wire is lost power, it is evident that economy requires that transmission of electric power be accomplished by high voltage and relatively small currents rather than the reverse. Thus it may be commercially possible to utilize a water power at a distance from a city to make high-voltage current which can economically be transmitted to the city over a line of rather small copper wires. It would never do, however, to carry this high-voltage current into buildings on account of the great fire risk involved, for the insulations in wiring cannot be made safe for high voltages. With direct current there is no very economical way to change a small current at high voltage into a larger current at a lower and safer voltage. With alternating current, however, this can be done very readily by means of a "transformer," a device which consists in its simplest form of two entirely separate coils of wire wound on the same iron core; in fact, a sort of double-coil magnet.

Fig. 13. Interior View of Incandescent-Lighting Transformer

Fig. 12 shows two shapes which a transformer may take. In each diagram suppose an alternating current at 2,200 volts and 1

ampere is supplied to one coil of 100 turns. Then a current of 220 volts and 10 amperes will be induced in the other coil which has but 10 turns, that is, the voltage will be "stepped down" in the same ratio as the number of turns on the *primary* (power-supply) coil and *secondary* (power-using) coil, and if there were no power loss in the transformer itself, the current would be multiplied by the same ratio inverted. In the case illustrated there are one-tenth as many turns in the secondary coil as in the primary and, therefore, the secondary voltage will be $\frac{2200 \times 1}{10} = 220$ volts, and the secondary current will be approximately ten amperes for every ampere supplied to the primary. If the power were supplied to the coil of the transformer having few turns, and used by the current induced in the coil having more turns, we should have a "step-up" instead of "step-down" transformer.

Fig. 14. Exterior View of Incandescent Lighting Transformer

It should be especially noted that the action of a transformer depends wholly on the principle that the rapid changes and reversals of current in one coil will induce currents in the other coil. Alternating currents are rapidly and systematically changing and reversing currents, and thus transformers can be used to change the voltage and currents in a. c. circuits. Direct currents do not change in amount and direction and, therefore, transformers cannot be used at all on direct current.

Figs. 13 and 14 show the interior and exterior views of a small transformer of a type used for incandescent lighting. The case is designed to be filled with oil. Transformers are constructed of all sizes up to very large units, and are cooled either by air, air blast, oil, or by forced circulation of oil through the windings and core.

Alternating-current dynamos and transformers are constructed and connected in several ways which differ in regard to the number of partially independent circuits which they supply. An a. c. circuit in which there are but two wires from the generator to the trans-

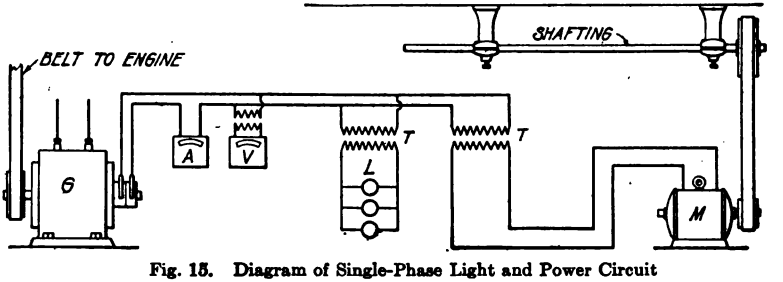


Fig. 15. Diagram of Single-Phase Light and Power Circuit

former or to lamps or motors is called a *single-phase* circuit. Fig. 15 shows the path of the current in a single-phase circuit which includes a generator G, switchboard with ammeter A and voltmeter V, transformers TT supplying power to lamps L and single-phase motor M. Single-phase circuits are used for lighting, both incandescent and arc, and for power.

The other most common type of a. c. circuit is called *three-phase*, and is also used both for light and power. The essential parts of such a system are shown in Fig. 16 where it will be noted that the dynamo has three slip rings, the circuit has three wires and the transformer has three coils in the primary T_1, and three in the secondary T_2. In a three-phase circuit each pair of wires carries what may be considered a separate alternating current which varies in each pair in regular cycles, so that the maximum current in each

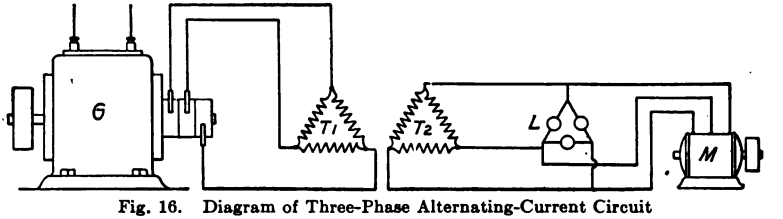


Fig. 16. Diagram of Three-Phase Alternating-Current Circuit

phase or pair of wires is reached at different instants of time. Such circuits are very widely used, especially for power, with what are known as three-phase induction motors.

Essential Parts of Electric Installations. For the general purposes of this book the essential parts of electric installations are as follows:

Generators. Generators include all dynamos and storage batteries. These present the hazards inherent in all machines of any sort which produce or transform large amounts of power.

Cables. Cables and wires used for transmitting electric power are of concern from a fire viewpoint because of the possibility of their becoming overheated by the current, and because failure of the means provided to confine the electric current to them, namely, insulation, may give rise to arcs, *i. e.*, flames from powerful electric sparks or discharges. The rules for safe wiring, therefore, are designed to limit currents on wires to safe values and to insure integrity and reliability in the insulations employed.

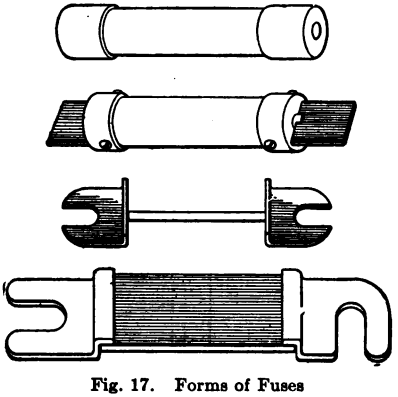


Fig. 17. Forms of Fuses

Closely associated with the conducting wires and cables are those devices which serve to regulate the amounts of current, to open and close electric circuits, or to change the characteristics of currents at or near the apparatus utilizing the power. Of this sort are *rheostats, switches, voltage-regulators, motor-generator sets, rectifiers,* and the very common *alternating-current transformer.* All these must have suitable insulation and mechanical protection, and there must be due protection from the heat or arcs which may be produced in them.

Power-Consuming Devices. The utilization of electric power, as of all power, is always accompanied by the production and dissipation of heat. Power-consuming electric appliances such as motors; all lamps, both arc and incandescent; heaters; and every other appliance using electric current, are, therefore, heat producers to a greater or less extent and must be so treated by the fire-prevention engineer.

Protective Devices. Protective devices are the safety valves of electric circuits. A fuse, Fig. 17, is a portion of an electric circuit

purposely made so that it will melt and open the circuit when the current rises to a value which creates dangerous conditions in other parts of the line. The proper design and use of fuses thus involves the two questions of suitable protection to the wires and appliances, and the liability of the fuse itself to cause a fire when it operates.

Circuit Breakers. Circuit breakers, Fig. 18, are automatic switches arranged to open the circuit if currents reach too great values. They thus accomplish mechanically the same results as fuses. As a general principle it may be remembered that high-

Fig. 18. Automatic Circuit Breaker

voltage circuits are more hazardous than low-voltage circuits, because they are more able to injure insulations and to produce arcs across gaps or from one wire to another. Large currents are not more dangerous than small currents so long as they have proportionally larger wires to carry them. In case of failure, however, large currents (many amperes) will cause more trouble. The persistency of an arc and the difficulty of suppressing it when once started, are dependent upon both the voltage and the current (amperes), but it is the voltage which causes arcs to form, as across air gaps or by puncturing insulation on a cable.

The production, transmission, and use of energy are necessarily attended with certain hazards which are in a sense proportionate to the amount of energy employed. The peculiar property of electrical energy is that a failure or accident to electrical appliances often permits a large amount of energy to be suddenly expended as, for example, at an arc or short-circuit, thus developing a great amount of heat.

NATIONAL ELECTRICAL CODE

As the result of the united efforts of insurance, electrical, architectural, manufacturing, and allied interests, there has been developed a comprehensive body of rules governing electrical work. The development and experience leading to these rules covered many years, but in 1897 what is known as the National Electrical Code*, was first issued by the National Board of Fire Underwriters with the approval of a large number of engineering associations of national scope, whose endorsement has given to these rules a standing and reputation unequaled by that of any other body of rules on an engineering topic in this or other countries.

The Code is generally admitted to represent the best opinion on electricity with relation to the fire hazard under the conditions existing in the United States. It is in general use by insurance companies, rating and inspection bureaus and departments, and engineering organizations. It is either adopted unchanged as the official body of rules for cities, or is, in some cases, used as the basis for the rules prescribed by the city government with a few changes or additions which are demanded by peculiar local conditions or which give greater protection against injury to persons than can be prescribed by fire insurance companies, which are, of course, not primarily concerned with the life hazard. These changes are, in nearly every case, of minor importance and consist usually of certain more stringent requirements than have found acceptance as a part of the Code. Few, if any, city rules are less exacting than the Code and nearly all are identical with its provisions.

It should be noted, however, that the Code does not attempt to prescribe the most efficient or economical means of applying electric currents, nor does it formulate engineering rules or practice,

*The National Electrical Code will hereafter be referred to as the "Code."

except in relation to fire hazards. It is published every two years following a public meeting in New York City at which all proposed changes or additions are thoroughly discussed. These meetings are held under the direction of the Electrical Committee of the National Fire Protection Association, a society the active members of which are insurance boards and bureaus, electric and architectural associations and institutes and other societies of national character. The Code has, therefore, the authority not only of underwriters, but also the indorsement of all the chief associations in the electrical and building industries and professions.

Twice every year (April and October) is issued the *List of Electrical Fittings* which gives, under the names of manufacturers, the devices which have been approved for use after samples have been examined and tested according to the construction rules of the code by Underwriters' Laboratories, an institution located in Chicago, Illinois, and maintained by insurance interests for the purpose of making investigations having a bearing on the fire hazard.

In the pages which follow, no attempt will be made to restate *all* of the rules of the Code, but rather to indicate the chief underlying principles of the rules and explain some of the reasons for them.

Copies of the Code can be obtained without cost from any insurance bureau and reference to the Code will be made freely in this book. It is, therefore, assumed that the reader has the Code before him and will refer to it for the official statement of the several rules, and for the relatively less important details not repeated in this text.

POWER STATIONS AND THEIR EQUIPMENT

There are some peculiar hazards present in stations or rooms used for generating electricity aside from those always involved where larger amounts of power are produced and controlled.

In the case of companies furnishing electricity for light and power, the generating and transforming stations are often of large size, and contain apparatus which is very expensive and also of enormous importance for the uninterrupted maintenance of the service they render. Modern practice, therefore, tends toward the

housing of such central plants in separate buildings of strictly fireproof construction, and the employment of every resource of engineering skill and experience to prevent fire from causing loss, either by the destruction of the equipment, or by interruption of service resulting therefrom.

The protection against fire in such stations thus becomes one of the chief considerations in the design of the whole plant and passes, therefore, in great measure into the field of the designing engineer. In any modern, well-designed central station the original equipment is usually fairly good from the viewpoint of fire hazard. The chief troubles often result from crowding equipment when it is found necessary to enlarge the capacity of the plant. Ample room for operating and for inspecting is absolutely essential. Accessibility of all portions of electrical equipment, the use of fireproof materials throughout, the installation of protective devices of approved design, and of ample capacity and arrangements, by which any trouble may be readily confined to a limited portion of the equipment, are chief requisites of a central-station equipment from the viewpoint of the electrical fire hazard.

Standard methods of installing generators, switchboards, and all transforming devices, should be followed, but the engineering requirements of special cases and the complexity and variety of such equipments in present-day stations render it manifestly impossible to describe in definite terms the details of construction and installation. In general, generators and motors of themselves present less hazard than the switchboards with the mass of wiring often found on them, the transformers with their charges of inflammable oil, or the large conductors carrying heavy currents and presenting large surfaces of combustible insulations.

Strict compliance with all accepted rules for wiring is of as great importance in central stations as elsewhere, both because of the large values involved, and because of the large amounts of energy to be controlled on the circuits. Central stations, therefore, should never be considered as outside of "Code rules" so far as they apply.

Generators. Generators for either central stations or isolated plants should always be located in a dry, light place as the presence of moisture is apt to injure the machines or may in extreme cases cause short-circuits in leads to the machine. No combustible ma-

terial should be permitted near a dynamo, and it is desirable that there should be good ventilation to maintain reasonably low temperature, thus increasing the capacity of the machine.

The presence of generators in rooms where any hazardous process is carried on is not to be allowed and it should be remembered that sparks from generator brushes or rings may readily set fire to inflammable gases or to flyings of lint. Generators operating at a potential in excess of 550 volts must have their base frames permanently and effectively grounded. Generators operating at 550 volts or less should be raised above the floor and should prefer-

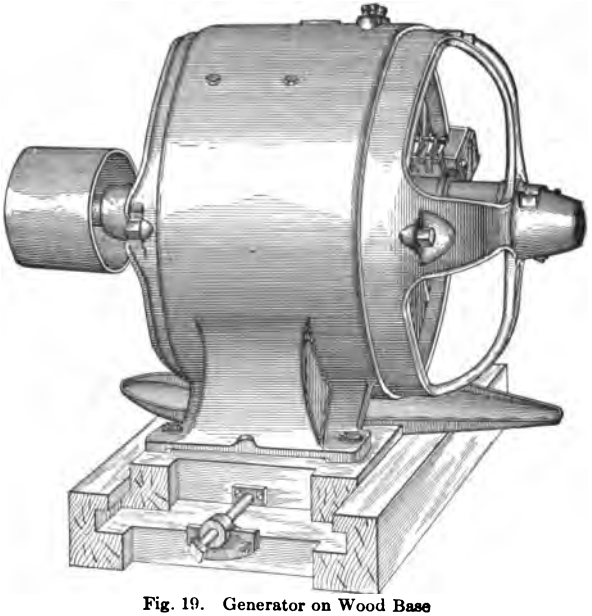


Fig. 19. Generator on Wood Base

ably be mounted on wood bases (Fig. 19) which insulate the machine frame. Such insulation will prevent a failure of insulation in the machine windings from grounding the system. Such a ground might cause a short circuit if the system became grounded at another point. If the frames are not insulated a reliable ground connection is required in order to give a *good* path for leak currents.

In generating plants supplying current to railway power lines, such as trolley and third-rail equipments, the current usually is carried to the trolley or third rail and returns after passing through

the car motors by means of the track rails and the ground. All feed wires from such generating stations must be protected at the station by an approved circuit breaker or similar device which will automatically cut off the current from the feed wires if an accidental ground might allow abnormally large currents to pass over the wire.

Dynamos in manufacturing plants are usually installed in the same rooms with the engines which drive them, and such rooms, therefore, present possible hazards from the exposure of wiring to steam piping and to mechanical injuries from whatever work may be done in repairs or alterations of machinery. The most common faults in such locations arise from crowding the electrical equipment into too small and inaccessible locations from a desire to use space

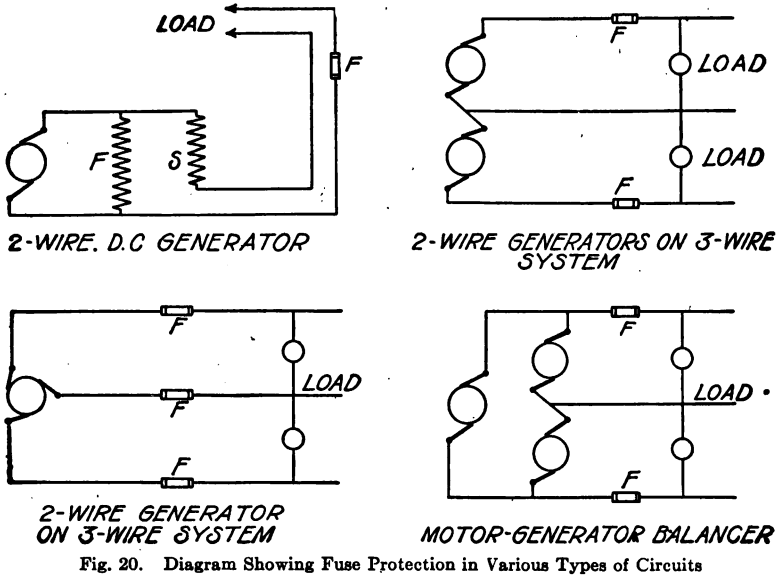


Fig. 20. Diagram Showing Fuse Protection in Various Types of Circuits

either not available for other uses or not especially planned for electrical apparatus. Convenience of operation, cleanliness of surroundings, and a workman-like layout of equipment, all contribute to the maintenance of good fire conditions. The requirements for overload protection at constant-potential generators are shown in the diagram, Fig. 20, where *F* in each figure represents the fuses or circuit breakers required by the Code. These fuses and breakers will usually be located on the main switchboard. This leaves

the large main cables from generators to switchboard unprotected and for this reason special pains should be taken with their installation since an accident to them might be very serious.

Generator-Room Wiring. All wiring in generator rooms should be done in the most substantial manner, and special attention should be given to simplicity and orderliness of arrangement. All supports for conductors must be very substantial. Fig. 21 shows an excellent example of a large mass of wiring well installed.

All wiring should be readily renewable and accessible. This usually requires either open wiring or some form of conduit. A

Fig. 21. Example of Large Mass of Wiring Well Installed

fiber conduit is largely used for this work and gives good results. The large amount of wire and cable often found in dynamo rooms, together with the large currents carried on the conductors, makes it necessary especially about switchboards to cover the highly inflammable rubber and braided coverings with a tight jacket of some non-combustible material, such as asbestos, to reduce the probability of fire spreading rapidly over all the exposed wiring.

Bus bars are usually left bare but there should be as little other bare current-carrying metal as possible.

All conductors should have ample current capacity, and in their

installation special care must be given to securing excellent insulation and reliable supports. Due regard should be given to the possibility of injury to conductors by tools, belts, ladders, etc., or by any vibration which may cause a gradual wear on wire coverings.

In general, the requirements of Class C of the Code apply to dynamo-room wiring with such special precautions as are dictated

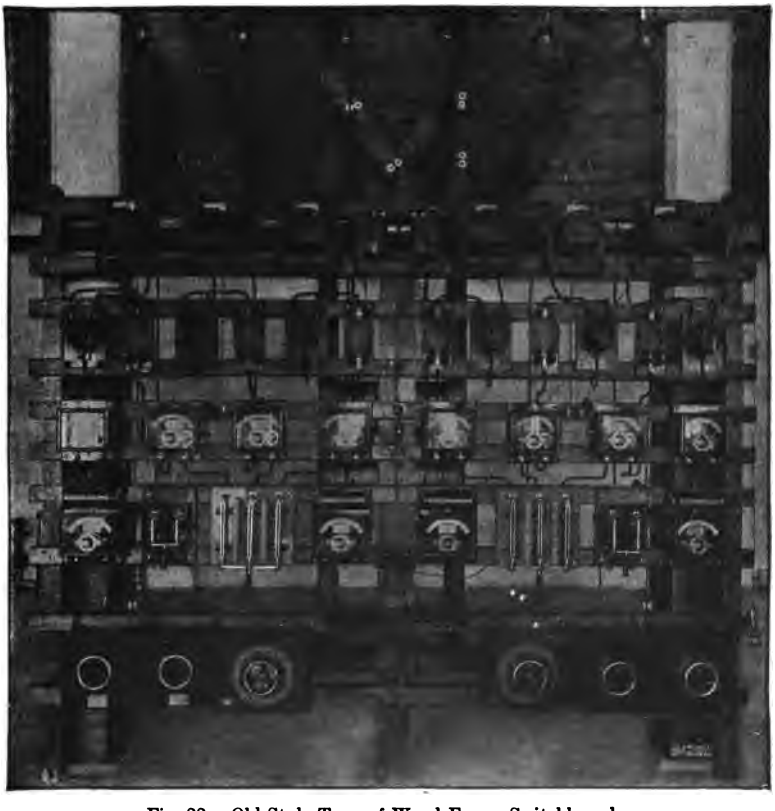


Fig. 22. Old-Style Type of Wood-Frame Switchboard

by the large currents to be cared for and the presence of a great number of conductors which may have to be placed rather closely together.

Switchboards. The danger of fire at switchboards lies in the large number of wires usually concentrated on them, and the use of rheostats, fuses, and other appliances which are possible sources of fire. The switchboard itself should always be of slate marble, or

other strong non-combustible insulating material. The old wood racks (see Fig. 22) once used are no longer permitted. Fig. 23 shows a small, well-arranged switchboard. While the front of the switchboard is the operating side, the rear is the part where trouble is more likely to occur. The back of the board should, therefore, be easily accessible and neatness of arrangement and reliable supports for all

Fig. 23.* Approved Type of Small Switchboard

conductors be imperative. No makeshifts are tolerable on switchboards under any conditions. Fig. 24 shows the back of a board. Every precaution must be taken to keep water or even moisture off switchboards since a short-circuit would be easily started and the result would often be highly disastrous. The Code, Rule 3, gives in detail some requirements for location and care of switchboards, the reasons for which are apparent without further explanation. Fig. 25 shows a large modern switchboard. In general the exact arrangement of parts on switchboards is determined by en-

*Courtesy Inspection Department, Associated Factory Mutual Fire Insurance Companies. Boston, Mass.

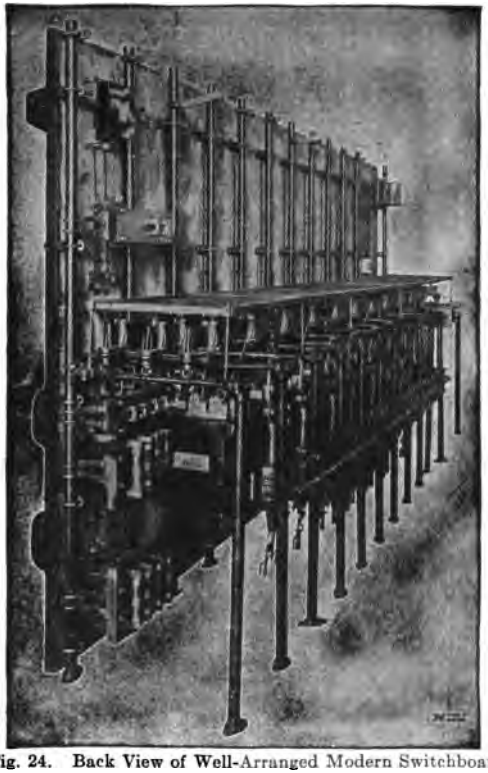


Fig. 24. Back View of Well-Arranged Modern Switchboard

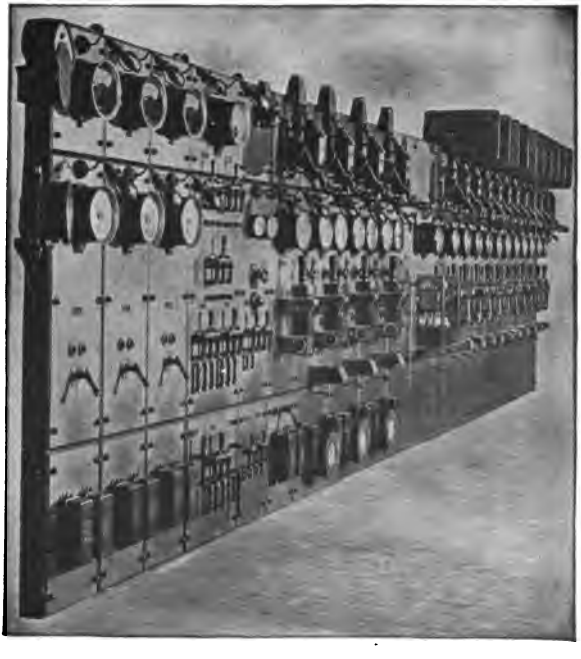


Fig. 25. Front View of Large Modern Switchboard

gineering and operating requirements, and the interest, from the viewpoint of fire, centers in the protection of conductors and the location of board and instruments to reduce the probability of fire spreading from the board to the other parts of the building. Orderliness and cleanliness should be insisted upon.

Resistance Boxes or Rheostats. These are used in a great variety of sizes and designs with dynamos and motors and at switchboards. They may be mounted either on the machines or switchboards or separately, but in every case they must be considered as "stoves" and liable to become "red-hot." The fact that they do not become hot when used under normal conditions is not to be considered as in any way lessening the requirements for protection.

Fig. 26. Interior View of Small Starting Rheostat

A burn-out of a rheostat may result in a mass of flames from the numerous wires, usually contained in or leading to the device, and there may be drops or spurts of melted solder or other metal. Fig. 26 shows the interior of a small starting rheostat.

All resistance devices used for starting, regulating, and controlling machines are to be classed as "resistances" in the intent of the Rules, and so in general are all devices or parts of devices where coils of wire, iron grids, or other similar objects are made parts of the circuit.

Lightning Arresters. The purpose of these devices is to prevent lightning, or external high-voltage currents from foreign circuits, entering the station and there causing fire or damaging machinery and instruments. Lightning cannot be "stopped" but may be *diverted* to the earth. A large variety of lightning arresters are on the market but they are all designed to afford a path by which discharges may pass to "ground" instead of into the station apparatus and to prevent so far as possible the normal currents on the lines from following this path. The operation of many lightning arresters is accompanied by sparks which may in severe cases assume the size of powerful arcs. The location of these devices away from all

combustible material is thus imperative. They are often installed in separate buildings with other emergency appliances.

The full discussion of lightning-arrester construction, operation, and installation is impracticable in this book. Suitable location, the running of connections in straight lines with the fewest

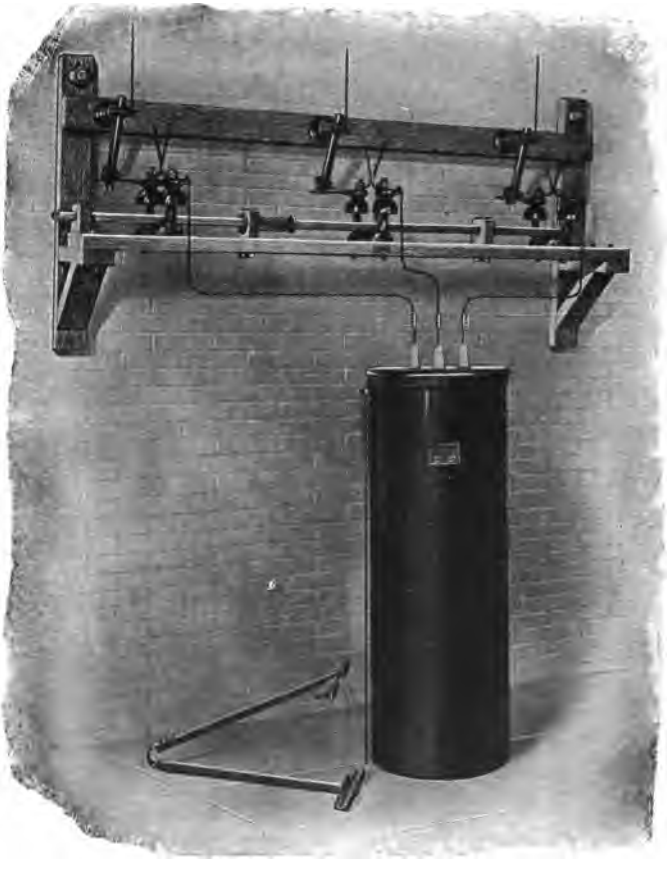


Fig. 27. Electrolytic Lightning Arrester for 7,000 Volts

possible bends, the use for ground wires of copper wire not smaller than No. 6, and especially the securing of permanently good ground connections are the chief considerations. Two separate ground connections are often desirable. Fig. 27 shows a type of electrolytic lightning arrester for 7,000 volts maximum potential to be used on three-phase circuits.

Ground Detectors and Tests. Except where circuits are intentionally and permanently grounded, a leak to "ground" may be the cause of arcs at some points in the system which may be dangerous. By "ground" is to be understood the earth, walls or floors of masonry, pipes of any kind, iron beams or floors and the like. It is, therefore, required that suitable instruments and circuits be provided to indicate either continuously, or by frequent tests, whether there are such ground connections which would indicate a failure of some insulation. If such a failure is shown by the detector the trouble can usually be located and repaired before injury is done.

Ground detectors may take the form of special instruments on the switchboard or of arrangements of switches with lamps or volt-

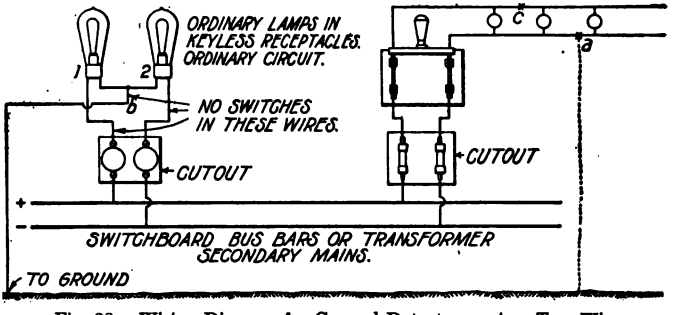


Fig. 28. Wiring Diagram for Ground Detector on Any Two-Wire Low-Voltage System

meters which can be used to test the insulation of each side of each circuit in turn. The connections should be such that the detector cannot be left out of circuit. For the various arrangements of ground detectors reference must be made to the standard electrical treatises.

Attention may be called to the following points which are frequently neglected:

(1) Lamp receptacles should be keyless and any switches in the detector circuits should be so connected that the detector will continuously give an indication on at least one side of the circuit.

(2) The wires should always be protected by small fuses where they connect to the bus bars.

(3) If the detector is of a type depending on relative brightness of two lamps, the lamps should be very close together.

(4) Special care should be taken to secure excellent ground connection for the ground wire.

The accompanying diagram, Fig. 28, shows a very good and simple detector for any two-wire low-voltage system, and is typical of many in use. (The diagram and description are taken from a publication of the Associated Mutual Fire Insurance Companies.)

The lamp for the detector should be of the same candle power and voltage, the voltage being about the same as that of the regular lamps in the plant, and two lamps should be selected which, when connected in series, burn with equal brilliancy. Although somewhat greater sensitiveness can be obtained with low-candle-power lamps, such as 8 c. p. for example, it is believed in general to be preferable to use lamps of the same candle power as those throughout the plant, as then a burned-out or broken-detector lamp can be immediately replaced by a good lamp from the regular stock, thus avoiding the necessity of keeping on hand a few spare special lamps.

The detector lamps, being two in series across the proper voltage for one lamp, burn only dimly. If, however, a ground occurs on any circuit, as at *a*, the current from the positive bus bar through lamp No. 1 divides on reaching *b*, instead of all going through lamp No. 2, as it did when there was no ground. Part now goes down the ground wire and through the ground to *a*, as indicated by the broken line, and thence through the wires to the negative bus bar. This reduces the resistance from *b* to the negative bus bar, and, therefore, more current flows through lamp No. 1 than before, while less current flows through lamp No. 2. Lamp No. 1 consequently brightens and lamp No. 2 dims. If the ground had occurred at *c* instead of *a*, lamp No. 2 would have brightened and lamp No. 1 dimmed. This detector, while not able to indicate extremely small leaks, will show any leak that is likely to be dangerous from a fire standpoint.

Motors. Electric motors are very generally used in manufacturing plants of all sorts and their use is still rapidly increasing. They are also used very extensively for elevators, cranes, and for an infinite variety of uses in all classes of buildings. Recently portable motors of small size have come into very general use for drills, and other portable tools, vacuum cleaners, washing machines, and scores of other purposes where their cleanliness, economy, and adaptability recommends them. These portable types of motors, however, do not in general come under the rules prescribed for stationary machines, though their use involves similar hazards and some others peculiar to themselves. These will be discussed later.

In general the same precautions should be taken with motors as with generators. Dry, clean, well-lighted locations should be chosen for them. It is a very common fault to install a motor in a space too small for it, or in a place where rubbish and dirt are allowed

to accumulate. The fact that modern motors are very sturdy machines, and will continue to work even when neglected and abused, encourages carelessness in maintenance which often results in hazardous conditions. Except where unavoidable, motors must never be located in the vicinity of combustibles, in wet places, or in very dusty or dirty places. When such locations are unavoidable, an "enclosed" type of motor should be used, or a special room, Fig. 29, should be provided. Many modern types of alternating-current motors have

Fig. 29.* Approved Housing for Motor in Bad Location

no exposed live parts and do not have commutators or brushes and are, therefore, well suited to dusty or linty places. Fig. 30 shows a rough commutator of a motor. It is evident that as the commutator revolves, the brush which carries the main motor current will not fit well at all points and, therefore, sparking will result. In extreme cases this sparking may be dangerous, especially in dusty places or where inflammable gases are present. Where motors are used, not of enclosed types with brushes, commutators or slip rings, where sparking may occur, special enclosures should be provided. The installation of motors on ceilings, Fig. 31, or built in as parts of the special machines which they drive, often affords both the neatest

*Courtesy Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.

and the safest arrangement. Motors operating at voltages over 550 volts require special precautions in respect to wiring leading to them. Motors for less than 550 volts are wired according to the general rules for low-potential systems.

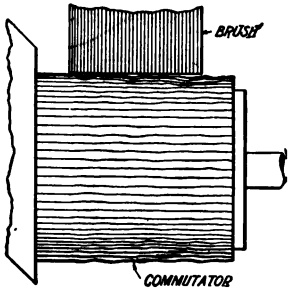


Fig. 30. Rough Motor Commutator Increases Sparking

Wiring to Motors. The supply leads to motors must be of a size to carry at least 25 per cent more current than that for which the motor is rated. This applies to all types of motors both d. c. and a. c. and is required even though the motor is not actually being used for its full load. This is called for to provide for the currents required to start the motor which are almost always greater than the current needed for continuous full load running, and also to safeguard the motor against exceptionally heavy currents, thus providing a margin of safety at all times.

Wiring for Direct-Current Motors. The Code prescribes the safe carrying capacity of wires of different sizes, Page 65. Thus if a direct-current motor requires 44 amperes when working under full load, the lead wire must be of such size as to carry 55 amperes. A reference to Rule 18 shows that this will call for a No. 6 wire.

The factors which are involved in the determination of the proper size of leads to direct-current motors may be summed up as follows:

Fig. 31.* Approved Ceiling Mounting for Motor

*Courtesy Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass

TABLE I

Size of Wires for Direct-Current Motors

Horse Power	110 VOLTS			220 VOLTS			500 VOLTS
	Full Load Current	Size of Wire Mains	Size of Wire Branches	Full Load Current	Size of Wire Mains	Size of Wire Branches	Open
1	8	14	14	4	14	14	14
2	15	12	10	8	14	14	14
3	23	10	8	12	14	12	14
4	30	8	6	15	12	10	14
5	38	6	6	19	10	10	14
7.5	56	4	3	28	8	6	14
10	75	3	1	38	6	6	12
12.5	94	1	0	47	5	4	10
15	113	0	00	56	4	3	10
17.5	131	00	000	65	4	2	8
20	150	00	0000	75	3	1	8
25	188	0000 c. m.	250	94	1	0	6
30	225	250	350	113	0	00	5
35	263	300	400	131	00	000	4
40	300	350	500	150	00	0000	3
45	338	400	600	169	000	c. m. 250	
50	375	500	700	188	0000	250	1

Column headed "Size of Wire, Branches" gives size of wires for branches and for mains supplying one motor and is based on the 25% overload demanded by the rule.

Column headed "Size of Wire, Mains" gives size of wire to be used for mains, but in no case must the size of these mains be less than that required for the 25% overload on the largest motor such mains supply.

The question of drop is not taken into consideration in these tables.

E = volts required by motor

k = efficiency of motor

h.p. = rated horse-power of motor

Then if I = current in amperes at full load and at the given voltage

$$I = \frac{\text{h.p.} \times 746}{E \times k}$$

When I is found, a reference to the Wire Capacity Table, Page 65, will show what size of wire is required for current 25 per cent in excess of I.

In Table I are given the sizes of conductors in Brown and Sharpe gauge required for direct-current motors for 110 and 220 volts for different sized motors from 1 up to 50 horsepower. The table is taken from the rules of the City of Chicago; other cities have slightly different rules.

TABLE II

Sizes of Wires for Alternating-Current Motors

SINGLE PHASE

Horse Power	110 VOLTS		220 VOLTS	
	Full Load Current	Size of Wire	Full Load Current	Size of Wire
1	12	12	6	14
2	23	8	11	12
3	33	4	16	10
4	44	4	22	8
5	53	2	26	6

Size of Wires for Three-Phase Motors

THREE PHASE

Horse Power	220 VOLTS			440 VOLTS		
	Full Load Current	Size of Wire Mains	Size of Wire Branches	Full Load Current	Size of Wire Mains	Size of Wire Branches
1	3	14	14	2	14	14
2	5	14	14	3	14	14
3	8	14	12	4	14	14
4	10	14	12	5	14	14
5	13	12	10	6	14	14
7.5	19	10	8	10	14	12
10	26	8	6	13	12	10
12.5	32	8	5	16	12	10
15	38	6	4	19	10	8
17.5	45	6	3	22	10	8
20	51	5	3	26	8	6
25	64	4	1	32	8	5
30	77	3	0	38	6	4
35	90	2	00	45	6	3
40	102	1	00	51	5	3
45	115	0	000	58	4	2
50	128	0	0000	64	4	1

Column headed "Size of Wire, Branches" gives size of wire for branches and for mains supplying one motor and is based on the 50% overload demanded by the rule.

Column headed "Size of Wire, Mains" gives size of wire to be used for mains, but in no case must the size of these mains be less than that required for the 50% overload on the largest motor such main supplies.

The question of drop is not taken into consideration in these tables.

Wiring for Alternating-Current Motors. The calculations for proper sizes of wires for alternating-current motors, are somewhat more complicated than for direct-current motors.

Table II gives the wire sizes prescribed by the rules of the Department of Electricity of the City of Chicago. Somewhat different values are, however, in use in other places and no universally accepted rule has yet been developed.

Switches and Protective Devices with Motors. Every motor of over ¼ horse-power must be protected by fuses or circuit breakers, and controlled by a switch; and all of these must be located within sight of the motor, and be arranged so as to open and to protect all the wires. An automatic circuit breaker which will disconnect all the wires of the circuit is considered the equivalent of both the fuses and the switch.

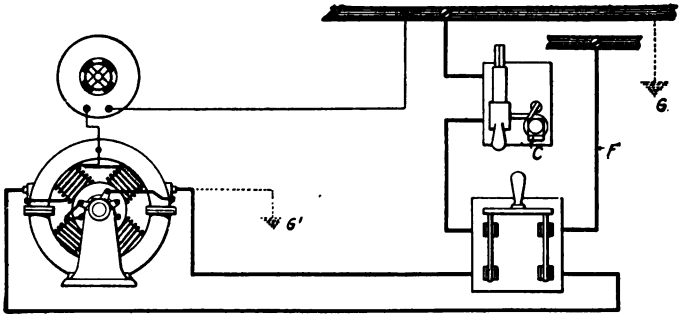


Fig. 32. Wiring Diagram of Motor Circuit Showing Inadequate Fuse Protection

The chief purpose of the fuses is to protect the motor and especially the wiring to it from overloads resulting from accidents to the motor or from the excessive current which will flow if an attempt is made to start the motor when it is for any reason unable to start and attain its proper speed. The fuses must, therefore, always be of such size as to blow with currents not in excess of the specified carrying capacity of the supply wires. Circuit breakers must not be set more than 30 per cent above the carrying capacity of the wire unless fuses are also used. Where rubber-covered wire is used for the leads or branches of alternating-current motors of the types requiring large starting currents, the wire may be protected in accordance with Table III on page 65, except when circuit breakers are installed which are equipped with time element devices.

Each wire of motor circuits, except on main switchboard or when otherwise subject to competent supervision, must be protected by an approved fuse whether automatic overload circuit breakers are installed or not. Single-phase motors may have one side protected by an approved automatic overload circuit breaker only if the other side is protected by an approved fuse.

For wiring circuits which have a maximum capacity greater than that for which enclosed fuses are approved, automatic overload circuit breakers alone will be approved.

Fig. 33. Small Ventilating Outfit to be Connected to Lamp Socket

The switch at a motor is required so that the line can be readily disconnected from the motor when the latter is not in use or in case of accident. On two-wire systems, a double-pole switch is required, on three-wire, a triple-pole. If a circuit breaker is used without fuses it must be of a type which will protect the motor under all circumstances. Thus in Fig. 32 the single-coil circuit breaker does *not* comply with the rule, since, if a ground should occur on the main at G and another on the motor at G^1, the coil C of the circuit breaker would be cut out of the circuit and the breaker would fail to operate, for no provision is made to open the other line. In this case a fuse of proper size should be installed at F or a circuit breaker having a trip coil in *each side* should be substituted for the fuse and breaker shown in Fig. 32. If the circuit breaker takes the place of the switch at the motor it must be such that one line cannot be opened without opening also all the others.

Motors of $\frac{1}{4}$ h.p. or less may be connected to circuits less than 300 volts in the same way as incandescent lamps, provided the proper fuses are used in the branches supplying the power to them. Such motors, illustrated by desk-fan motors and all portable motors

of small size, do not usually require starting rheostats. Fig. 33 shows a small ventilating outfit to be connected to a lamp socket.

Rheostats with Motors. Rheostats are used with motors for starting them and for controlling their speed. They should always be regarded as sources of heat and installed accordingly. Fig. 34 shows a common type of motor-starting rheostat. Such rheostats (called motor starters) need to be in the circuit for only the very short time usually required to bring the motor up to speed and, therefore, they are usually so designed to carry the necessary current for only this brief period. Such motor starters, if left with current passing through their coils or grids for longer periods, will become very hot and may burn out. The manner in which a simple motor starter is connected is shown in Fig. 35 when *A* represents the armature of the motor, *M* the field coil or electromagnet of the motor and *R* the resistance coils in the starter rheostat box. The required fuses and switch are shown at *FF* and *S*. In this design the starter, fuses, and switch are all mounted on a single slate base. To start the motor, the switch *S* is first closed and the handle *H* is slowly moved from *O* to the position shown in the diagram. It will be seen that the resistance *R* during the process of starting serves to limit the current supplied to the motor armature, which would otherwise, until the motor came up to speed, be excessively large. When the handle has reached the position shown, the resistance is all cut out of the circuit. A rheostat of this sort cannot be used safely except to *start* a motor of the proper size for it. The resistances will get excessively hot if *H* is allowed to remain at any intermediate point.

Fig. 34. Common Type of Motor Rheostat

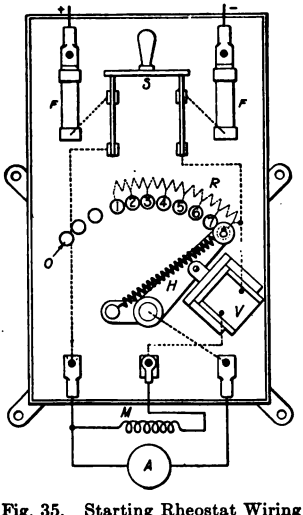


Fig. 35. Starting Rheostat Wiring Diagram

Motor starters for d. c. motors must, therefore, be made so that a spring or other device will return the lever to the "off" position in case the operator attempts to leave the starter with current passing through its resistance coils. This is because these coils are not designed for this continuous duty. When, however, the lever has been moved clear across to its final position, it is held there by a small electromagnet (*V* in Fig. 35) but in this position the connections have been shifted so that the resistance coils are no longer in the circuit. If now it should happen that the supply of current should fail, the electromagnet (called the *no-voltage release*) will release the lever which will fly back to the original "off" position. Then when the supply is re-established the motor will not be injured by starting too suddenly, or by the severe arcing at the motor commutator.

Since a. c. motors usually have no commutators and are less liable to injury from sudden starting, a no-voltage release is not required in a. c. starters.

A somewhat different device called an *autostarter, potential starter,* or *compensator,* is often used for starting a. c. motors. It is a form of transformer which allows only a portion of the line voltages to be applied to the motor until it is well started. Autostarters are to be regarded as sources of heat, and much the same precautions are necessary as with ordinary starters containing wire coils or iron grids. If they contain oil-immersed switches or coils, the oil adds a further hazard on becoming overheated or spattered about. Fig. 36 shows the interior of a compensator.

Fig. 36. Interior View of Compensator

In general, motor starters, either d. c. or a. c., involve both the hazards of switches and those of possibly overheated coils of wire or other parts, and must be treated accordingly.

Another class of rheostats includes those which are intended for regulating the speed of motors and generators. They are necessarily used continuously whenever the machine is running and, therefore, must be proportioned so that their coils or other resistances

will not become overheated, even when the necessary current traverses them for hours at a time. Fig. 37 shows a large rheostat of this type. Among these rheostats are classed field rheostats for dynamos, controllers for motors (as distinguished from motor starters), theater lamp dimmers, and, in fact, *all* rheostats or resistances which are required to be continually in the circuit. Some motor starters are designed to serve also as controllers and may have two sets of resistances, one for starting only and the other for continuous duty in varying the speed of the motor. These are especially useful in connection with machine tools and similar apparatus.

Special forms of rheostats having their resistances so enclosed that a burn-out will not cause sparks, are required in dusty or linty

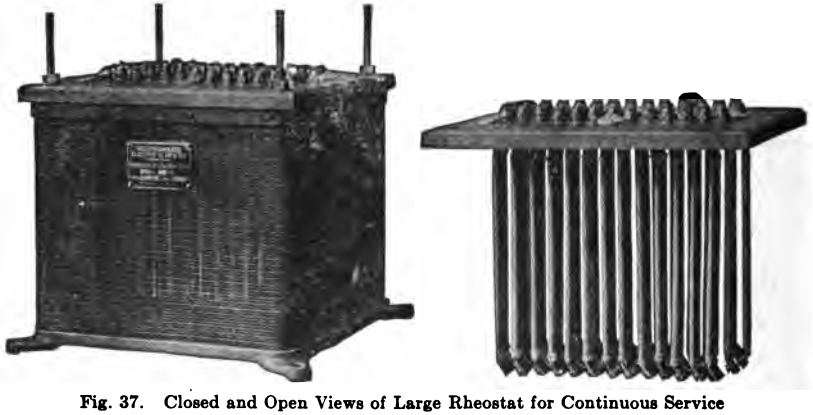


Fig. 37. Closed and Open Views of Large Rheostat for Continuous Service

places, such as flour mills, various textile mills, etc. If such specially protected starters are not supplied, the starting apparatus should be in special rooms where the dust or lint can be kept out.

The dangers to be guarded against in all rheostats of every type arise from the fact that these appliances must from their very nature be sources of heat. By liberal design and good ventilation the *temperatures* can be kept low; but all rheostats should be installed with the idea that they may become overheated by failure or misuse, Fig. 38. The large amount of insulated wire often used, and the oil in which parts are sometimes immersed, may furnish a considerable amount of fuel, and in severe burn-outs, flames may result and molten metal be ejected. A large amount of smoke usually accompanies a burn-out of a rheostat.

Storage Batteries. Batteries of large size are now in common use. These are practically always storage batteries, that is, batteries which are recharged by having current from a generator

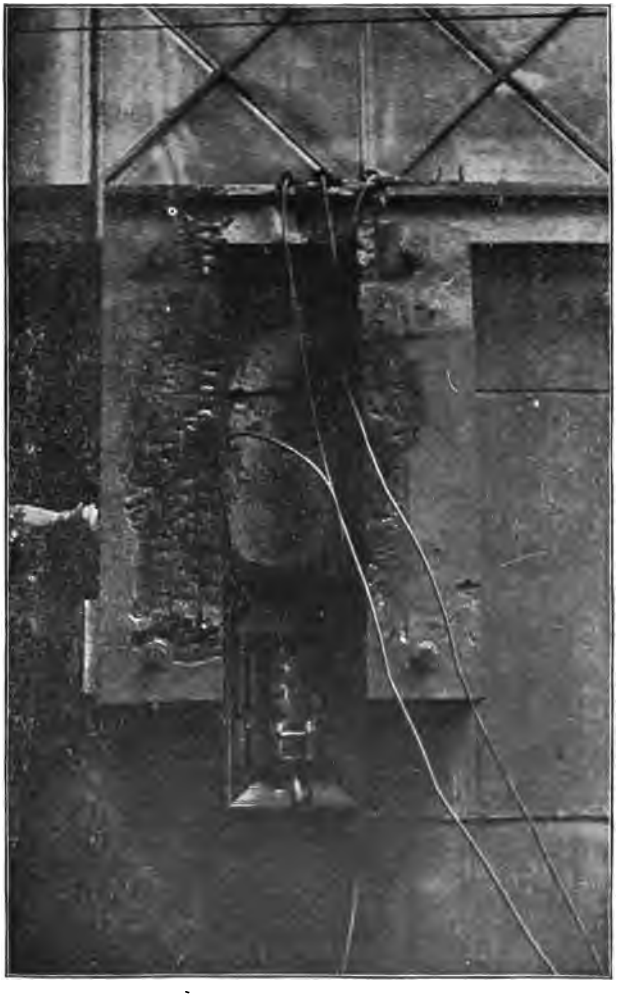


Fig. 38. Example of Badly Installed Rheostat and Switch

supplied to them from time to time. What are called primary batteries, that is cells in which there is a chemical action which sets up a current without any machine being used to charge and recharge

them, are sometimes of large size, and develop fairly high voltages. They are, however, used chiefly for telegraphs and other signaling work and need not often come under the supervision of underwriters or fire-protection engineers.

Storage cells, however, where they are capable of developing the same voltage (100 to 600 volts not uncommon) require the same general precautions as dynamos or motors since they produce like amounts of energy. Furthermore, it is a property of such batteries that in case of a short-circuit they can for a short time supply very large currents, far larger than they are normally called upon to supply. Thus they may be termed reservoirs of energy, capable of producing trouble if their output is not properly controlled.

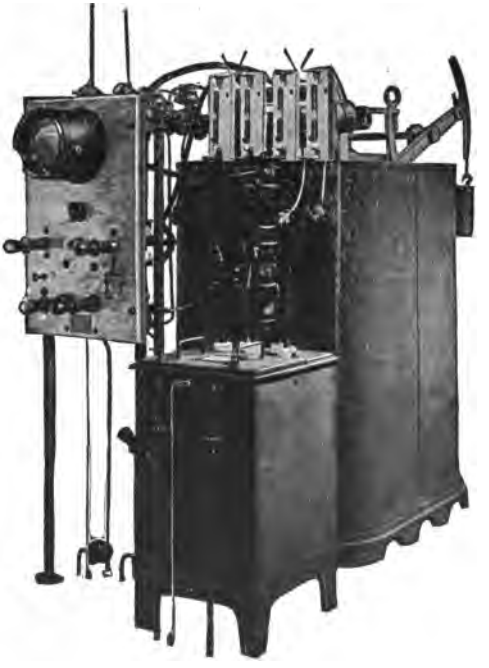


Fig. 39. General Electric Arc Lighting Transformer with Series Rectifier

Storage battery rooms should be thoroughly ventilated. The action of the current in charging the battery, liberates at times large quantities of hydrogen and oxygen, and if these should accumulate in the right proportions, they would form an explosive mixture which might be exploded by any accidental spark.

The water and acid used about storage batteries make it necessary to provide especially good insulation. The battery jars are best mounted on glass strips set on special porcelain insulators. The usual precautions for rooms where acid fumes exist should be taken in battery room wiring, and metal parts must not be such as to be affected by corrosion, since a decrease of the cross-section area of any current-carrying part may ultimately reduce the metal to a

degree that will cause overheating or, in case of an actual break, a dangerous arc.

Transformers. In central or substations or in large power rooms of isolated plants or factories, the chief point in the installation of transformers is the provision for preventing injury from the fire resulting from burning out of the coils or, in the case of oil-filled cases, from the boiling over of the oil. These effects are, of course, produced only from some accident to the apparatus or circuits, but transformer fires are peculiarly difficult to fight, and the oil and the insulations on the windings produce, at high temperature, large volumes of smoke which may damage goods in other parts of the building than the transformer room itself, or which might be mistaken for a fire and result in water being thrown into the building entailing a heavy "water loss." Transformers should always be located in clean, dry places with ample space about them. Fig. 39 shows a General Electric constant-current arc-lighting transformer with series rectifier outfit for 4-ampere 50-light system.

OUTSIDE WORK

Defects or failure of electric light or power circuits outside of buildings, as on poles or over the roofs or walls of buildings, may become the cause of fire by setting up abnormal conditions in appliances connected to them, by setting fire, either by overheating or arcing, to buildings on which they are supported, or especially by *crosses*. By a *cross* is meant an accidental touching by wires of one circuit or line with those of another line. By such accidental contacts lines may become charged with a higher voltage than they or their appliances are suited for. Thus a cross between a 2,200-volt arc-light wire and a 110-volt house-lighting circuit may cause current from the 2,200-volt circuit to pass into one or more houses where it will perhaps blow fuses with an explosive action, or cause very dangerous arcs as it passes to the ground through some defective insulation, Fig. 40. Similarly it is very dangerous for an ordinary lighting circuit to become crossed with a telephone wire, since the insulation and carrying capacity of telephone wiring is not such as to resist the effects which might be produced. For reasons such as these, outside wiring has a definite relation to fire hazard even in buildings.

Wiring. In very many cities and towns insufficient attention was paid to outside wiring until the streets and alleys became crowded with circuits of all sorts, each put up as was cheapest or most convenient at the time it was constructed. Where some of these circuits are of high power and high voltage exceedingly dangerous

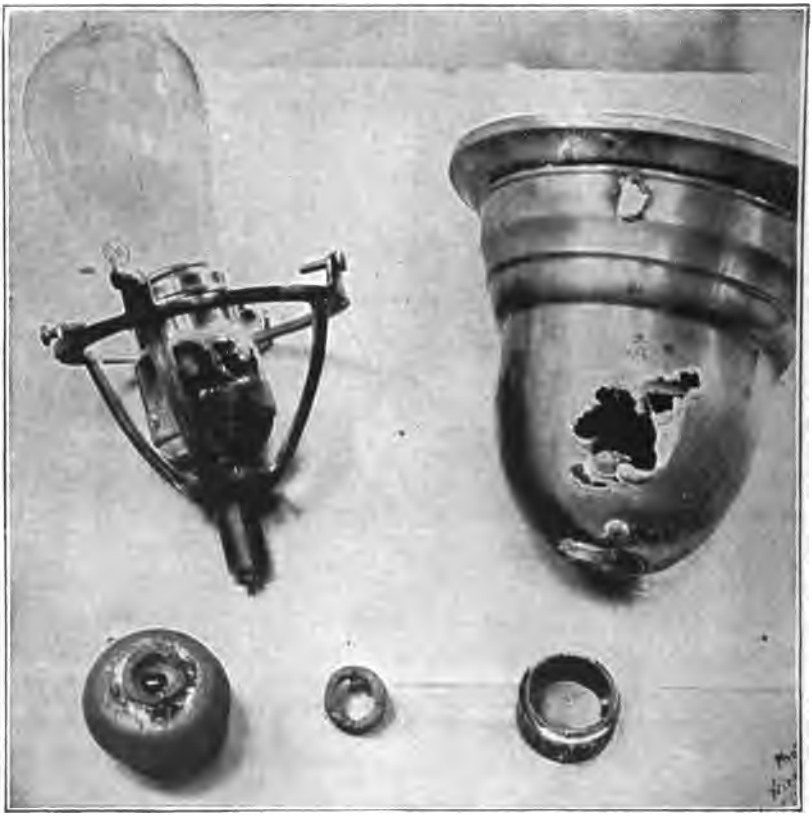


Fig. 40. Result of Cross Between 2,200-Volt Lighting Circuit and 110-Volt House Circuit

conditions exist, and the hazard may be extended over large areas remote from the place where actual failure occurs, since the resulting accidental currents may pass over any of the lines involved to buildings at considerable distances. The efforts of fire-protection engineers and insurance interests should be directed toward the correction of faulty outside wiring conditions, which if neglected are bound to

become progressively worse and constitute a serious menace to lives and property.

Where an insured property is clearly jeopardized by outdoor wiring, excellent electrical conditions indoors can at best afford only a partial safeguard, and fire-protection engineering should apply itself to remove the defects out-of-doors as well as in.

Underground System. The placing of electric wires underground, especially where low voltage and signal circuits are carried in separate conduit systems, affords the most thorough solution of the hazards of town and city wiring. Underground wires are, of course, less liable to accidents of weather and storm, and are, therefore, preferred by operating companies although the expense of putting wires underground often prevents or postpones a change. Legislation prescribing a gradual change, a certain amount of wiring being put underground each year, has often produced results without undue hardship to electric companies. However, there are certain well defined precautions and standard methods for outside work which can reduce hazards to a great extent.

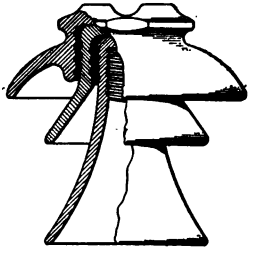


Fig. 41. Petticoat Insulator

Standard Practice. Line wires should have either rubber insulating or weatherproof covering. The weatherproof covering consists of three tight cotton braids, each of which is thoroughly impregnated with some kind of waterproof compound.

The insulation of outside wires on poles is required as an additional protection, but is not in any way depended on for insulation at the supports. The use of bare wires to hold the line wires would greatly increase the probability of crosses in cases of breakage of wires.

Standard practice is to use glass or porcelain insulators at least 1 foot apart on pole cross-arms and to ground all metallic sheaths of cables. Fig. 41 shows a cross-section of one form of porcelain insulator. The "petticoats" will nearly always have a dry space underneath their lower edges, and even if not dry, the length of the path offered to the current escaping over the wet surface is so great that the leakage is small.

All joint wires should be soldered and carefully insulated. The joint should be made mechanically and electrically secure before the solder is applied. Good joints are requisite to lessen the chance of wires falling as well as to prevent arcs on the wires themselves.

Proximity of Wires to Electric Light and Power Lines. Probably the most common and also the most dangerous fault in outside work

Fig. 42. Presence of Overhead Wires Hinders Firemen

is the running of telephone and other signal wires too close to electric light and power lines. Wires of this sort should never be on the same cross-arms and it is much the best practice wherever possible to keep telephone wires on poles on one side of a street, and light and power wires on the other, giving special attention to the necessary crossings, if any. In all outside pole work in towns due regard should be given to the fact that lines consisting of many wires are a serious hindrance to firemen in attacking a fire in the adjacent

buildings, Fig. 42. The disposition of the lines should be such as to reduce this as far as practicable; but placing wires underground is the only complete solution of this problem.

Fig. 43.* Well-Installed Roof Wiring

Outside Wires on Buildings. Where outside lines are supported on buildings, they should be at least 7 feet above the highest point of flat roofs and at least 1 foot above the ridge of pitch roofs over

Fig. 44.* Approved Form of Roof Structure for Safe Installation

which they pass and the roof structures should be of the most substantial description. Figs. 43 and 44 show two forms of roof structure which hold the wires high enough so that they cannot sag and

*Courtesy Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.

touch the roof and so that they are not liable to be touched or disturbed by persons walking on the roofs. Where outside wires are brought from pole lines into buildings special precaution must be taken. Such wires are spoken of as service wires or services.

The portion of such wires from the service switch in the building and the first outside support must be rubber insulated. Every precaution must be taken to keep service wires free from contact with cornices, awning-frames, shutters and the like, under all conditions. Usually, for low-voltage circuits, it is best to put the wires in metal conduit, as shown in Fig. 45. This drawing also shows the drip loops which should always be provided, the insulators on brackets secured to the wall and the special *pipe-cap* on the top of the conduit to keep rain out of the pipe. Where conduit is not used, porcelain bushings may be used, slanting upward through the wall toward the inside.

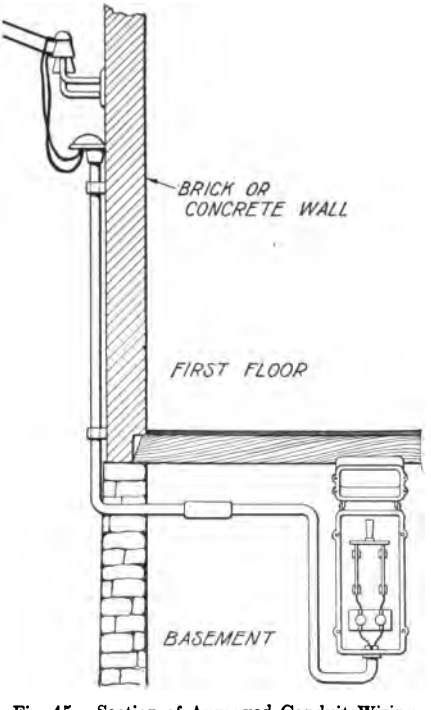


Fig. 45. Section of Approved Conduit Wiring Showing Provision Against Moisture

In general it is better to have service wires enter through the basement rather than through an upper story or attic. Where wires are carried along side walls outside of buildings, they should be supported on glass or porcelain insulators, not more than 15 feet apart. Where not exposed to weather, porcelain knobs may be used if not more than 4½ feet apart.

Trolley Wires. Trolley wires must be of ample size for mechanical strength (No. 0 B. & S. gauge copper or No. 4 B. & S. gauge silicon bronze). Protection against crosses must be ample and street railway trolleys and feeder cables must be capable of being disconnected at the power station or of being divided into sections so that in case

of fire on the railway route, the current may be cut off from the particular section and not interfere with the work of the firemen.

Electrolysis. Whenever an electric current passes between a pipe or wire underground into damp earth an electro-chemical effect is produced which may, under certain conditions, produce a disintegrating effect on the metal pipe or wire and eventually destroy it. Whenever an electric current passes through a conducting liquid which is not a chemical element, the liquid is decomposed. The salts and acids in the liquid are thus decomposed and metal plates by which the current is led into and out of the liquid are also affected. This process is called *electrolysis,* that is, breaking up of chemical composites by electric currents.

It is at once evident that water and gas pipes of iron buried in moist earth provide the necessary combination for electrolytic effects and that pipes in areas traversed by currents through the earth may

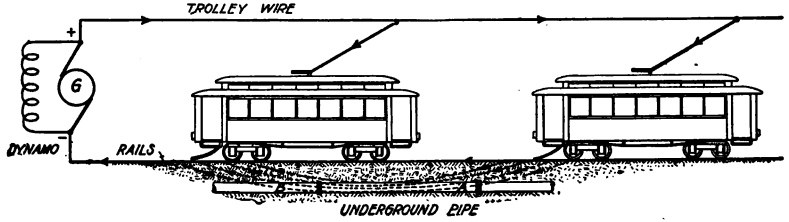


Fig. 46. Diagram of Electrolytic Effects of Street Railway Return Currents

be injured by such chemical disintegration. In cities and towns where there are large electric currents which use the earth as a "return path," these effects, if improper conditions are allowed to exist, may become very serious and have a bearing on the fire hazard chiefly as they may jeopardize the water mains and supply pipes to an extent sufficient to render the fire-fighting facilities unreliable in emergencies. Since the direction of alternating currents reverses many times each second, the chemical effects which they can produce are also reversed and, therefore, in general alternating currents in the earth are not liable to produce dangerous electrolysis. There are, however, direct currents which usually employ ground returns and by far the commonest are the currents of the usual overhead trolley street railways. It is to these, therefore, that the following explanation applies. Fig. 46 illustrates the way in which the current in a trolley circuit returns to the generator. Such circuits in this country

are almost invariably direct current at 500 to 650 volts and the *positive* side of the dynamo is regularly connected to the overhead wire. The current thus passes out over the trolley, through such cars as are in operation and back to the negative side of the dynamo, by the rails, or through pipes, moist earth or other conducting substances underground. The negative side of the generator is, of course, connected to the rails and ground. The return current divides according to the conductivity of the different paths afforded it and the actual distribution of currents in the earth may be very complicated and is subject to great variations from point to point. Careful "electrolytic surveys" are necessary in order to discover fully the actual current arrangements existing underground in any town or city.

In general, however, it is important to notice that wherever the current *leaves* a pipe for the earth, as at *B* in Fig. 46, the iron of the pipe is carried away into the earth, just as in a silver plating battery, silver is carried away from the silver plate toward the article which is being plated. It is this action which is meant by electrolysis as the term is usually employed with reference to underground pipes and earth currents and the result, as has been stated, may be a destruction of the pipe at one or at many points.

For the diminution of such electrolytic corrosion every means should be taken to afford a low-resistance path for the return circuit. This is also of advantage from the viewpoint of economical operation since it takes power to drive the current through a high-resistance return path. Large copper conductors are often laid between the rails and parallel to them, frequent heavy cross wires being used to connect this copper cable to the rails. Good bonds between rails either of low-resistance tie plates, or still better of electric welds between rail ends, are of great value.

The general arrangement and size of return wires and rail should be such that the difference of potential in volts between the grounded terminal of the generator and any point on the return circuit will not be more than 25 volts.

Where pipes or other underground metal work are found to be electrically positive to the rails or surrounding earth, that is, so that current tends to flow *from the pipes to the rails or earth*, special conductors should be provided to connect the pipes to the rails to

carry such currents and thus prevent, as far as possible, the effects of electrolysis. Very elaborate investigations of electrolysis as affecting water mains, gas pipes and other underground metal have been made in many cities and the co-operation of city authorities, water companies, and electric power and railway companies, has in many places resulted in greatly lessening, if not in entirely removing, the dangers from this cause. Surveys should be repeated occasionally since new electric circuits or new pipe lines may create an altered condition in underground distribution of currents.

High Tension Lines. In recent years there has, in most parts of the country, been a very great increase in the number of high-tension power-transmission lines and the voltages have also become much higher. Overhead lines of this class present certain problems

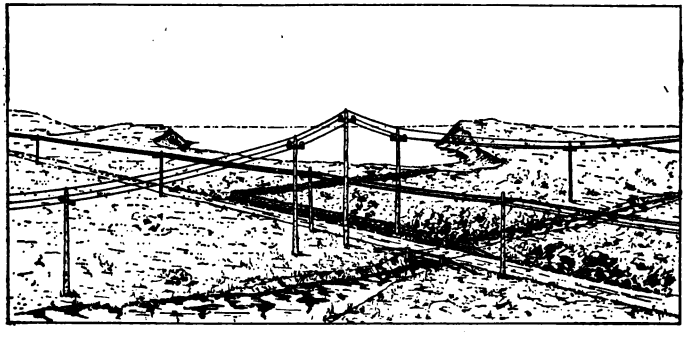


Fig. 47.* Crossover Arrangement for High-Tension Circuits

requiring very careful attention. The Code states the following causes of fire which may come from high-voltage (over 5,000) lines:

Accidental crosses between such lines and low-potential lines may allow the high-voltage current to enter buildings over a large section of adjoining country. Moreover, such high-voltage lines, if carried close to buildings, hamper the work of firemen in case of fire in the building. The object of the rules is so to direct this class of construction that no increase in fire hazard will result, while at the same time care has been taken to avoid restrictions which would unreasonably impede progress in electrical development.

It is fully understood that it is impossible to frame rules which will cover all conceivable cases that may arise in construction work of such an extended and varied nature, and it is advised that the Inspection Department having jurisdiction be freely consulted as to any modification of the rules in particular cases.

* *Courtesy Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.*

The very best way to guard against accidental crosses between high-tension lines and other circuits is to have them follow different routes. This can often be accomplished by mutual agreement of the parties interested even when a change in one of the routes will be necessitated.

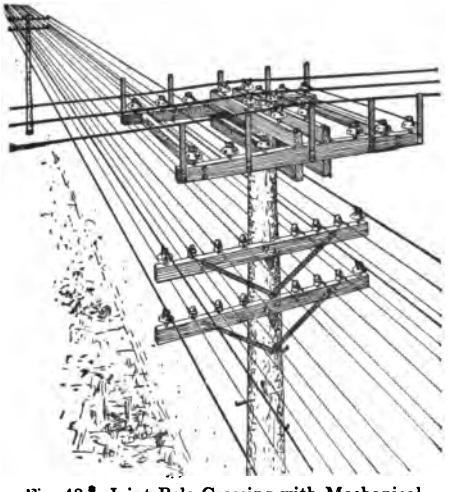


Fig. 48.* Joint-Pole Crossing with Mechanical Guards

High-tension lines should not approach other pole lines nearer than a distance equal to the height of the taller pole and such lines should not be on the same poles with any other lines except such signal lines as may be used by the company operating the high-tension system.

Where such lines must necessarily be carried nearer to other pole lines than is specified above, or where they must necessarily be carried on the same poles with other wires, extra precautions to reduce the liability of a breakdown to a minimum must be taken, such as the use of wires of ample mechanical strength, widely spaced cross-arms, short spans, double or extra heavy cross-arms, extra heavy pins, insulators, and poles thoroughly supported. If carried on the same poles with other wires, the high-pressure wires should be carried at least 3 feet above the other wires, but this arrangement should never be adopted unless it is impossible to do otherwise. Where such lines *cross* other lines, the poles of both lines must be of heavy and substantial construction.

Fig. 49.* Use of Screen on High-Tension Crossover

The Code contains quite detailed specifications for the safe

* *Courtesy Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.*

construction of crossovers and other details of high voltage lines which should be carefully studied and followed.

Fig. 47 shows one arrangement for a crossover. A *joint-pole crossing* may sometimes be used and Fig. 48 shows such a crossing with mechanical guards and wires on the upper or high-tension line cross-arms. Sometimes a screen either supported on high-tension insulators or grounded may be suspended between the lines at the crossover as illustrated in Fig. 49. When necessary to carry high-tension lines near buildings they should be at such height and distance from the building as not to interfere with firemen in event of a fire. Such interference might arise either from the difficulty of placing ladders or from the danger of shocks to firemen holding hose nozzles, streams from which might strike the high-tension lines.

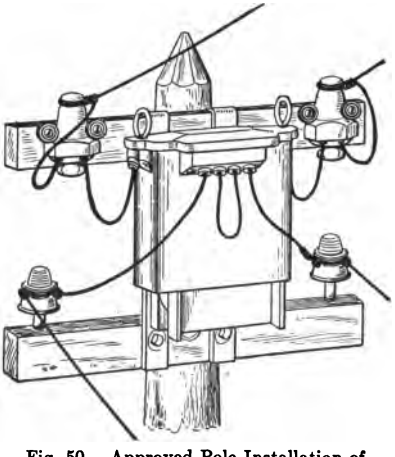


Fig. 50. Approved Pole Installation of Transformer

Mounting of Transformers. Oil-cooled transformers should not, in general, be installed in buildings, and an outside location is always preferable; *first*, because it keeps the high-voltage primary wires entirely out of the building; and *second*, because of the possible injury from smoke and oil in case the transformer burns out or is overloaded. Figs. 50, 51, and 52 show transformers installed on a pole, on the outside wall of a mill and in a special fireproof vault, respectively.

Grounding of Circuits. One of two courses should always be followed with regard to any electrical connection between circuits or apparatus and the earth; either arrange to have no such connection at all, and secure good insulation between live parts of circuits and the earth, or provide a good earth connection of sufficient capacity well installed to care for any current liable to pass to earth, either regularly or in case of accident.

In general it should be remembered, that if an entire electric circuit including the generator, lines, and all connected apparatus

and devices are thoroughly well insulated from the ground, *one* accidental ground will produce no effect since there is no return path from the ground to another point on the system. However, we cannot be sure that an installation will be kept free from grounds even if originally so installed, since wear, deterioration of insulating materials, breaking of parts of devices, or the effects of dirt and damp may bring on a "ground" which will not be discovered until a second ground connection is established which permits current to flow with consequent heating and arcing. Under such conditions, the fault is liable to become rapidly worse. Not the least important thing about such failures of electrical circuits, is the danger of injury to persons who may become a part of the ground circuit. Thus a mechanic working on a line shaft in a mill, by touching simultaneously a live part of the circuit or a poorly insulated live wire and the shafting, may make his body part of a path for the current to ground. While 110 volts or 220 volts either a. c. or d. c. are rarely enough to kill a person, painful accidents may be caused directly or indirectly by shock, and voltages of 440, 500, or higher may readily be the cause of death if the conditions are such as to permit any but very small currents to pass through the body. While, of course, liability of injury to persons is not a "fire hazard," still good construction should provide (both in original installation and in upkeep) all reasonable protection, to persons and property.

Fig. 51.* Approved Transformer Installation on Outside of Building

In direct-current three-wire systems of electrical distribution, the middle or neutral wire is regularly grounded at the central station. In systems where the cables are underground, the neutral must also

* *Courtesy Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.*

be grounded at each distributing box, through the box; and in overhead systems the neutral should be grounded every 500 feet. The neutral in such systems is supposed, normally, to carry either no current, or such small amount of current as may result from a different amount of power being temporarily taken from the two outside wires. If in any system the neutral is grounded at all, it should be done thoroughly so as to prevent the current escaping to ground where the connections may be so poor as to cause unsafe heating.

Two-wire direct-current systems are not to be grounded at all. Suppose in Fig. 53 some current-carrying part of the dynamo *D* is grounded, that is, in electrical connection with the earth, as through the bolt and the damp wood base of the machine. If this be all, no current will flow so long as there is no other ground connection to any other part of the circuit. But suppose that somewhere in the building a wire touches a gas pipe as at *B* and the insulation on the wire at *B* is worn by vibration or is defective for any reason. The gas pipe is, of course, connected to the earth and the current then has a path through the pipe, earth, bolt, base, and frame of the machine. The whole voltage of the dynamo may, therefore, drive current through this path, causing an arc to form at *B* between the wire and the pipe which will burn a hole in the pipe and set fire to the escaping gas. Evidently the greatest pains should be taken to prevent wires from coming in contact with grounded piping or other metal.

Fig. 52.* Transformer Installation in Fireproof Vault

Alternating-current systems almost invariably include transformers in which the higher line voltage is "stepped down" to the voltage required for lamps and motors. Common line voltages are 1,100, 2,200, and 3,300 volts, while the secondary voltages may be 100, 110, 220, 440 or 550. With such systems as are commonly used for distributing light and power, it is now required that the sec-

* *Courtesy Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.*

ondary or low-voltage side be grounded, provided the maximum difference of potential between the grounded point and any other point in the circuit does not exceed 150 volts and they *may* be grounded when this maximum difference of potential exceeds 150 volts. The ground connection may be made either at the transformers or at individual service entrances. At transformers the connection is made at the neutral or middle point of the secondary winding or coil. With three-wire a. c. distributing systems, the neutral wire itself is grounded. Sometimes, when a neutral point is not accessible, *one side* of the secondary circuit may be grounded.

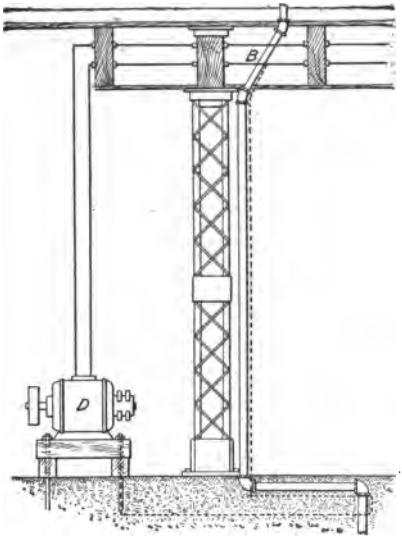


Fig. 53. Faulty Installation of Two-Wire Direct-Current Dynamo

It should be remembered that a poorly made earth connection may be worse than none. The rules, therefore, prescribe in detail how to secure *good* connections. The wire should be of large size and should be run in as nearly a straight line as possible, avoiding kinks, coils, and sharp bends which are objectionable since they impede the flow of alternating-current or lightning discharge.

Individual transformers and building services may be grounded to water pipes by carrying the ground wire into the basement and connecting it to the *street* side of meters, main cocks, etc., so that any resistance which these might offer in the ground path might be avoided.

The underwriters' rules give the following directions for making ground connections:

In connecting a ground wire to a piping system, the wire should be sweat into a lug attached to an approved clamp, and the clamp firmly bolted to the water pipe after all rust and scale have been removed; or be soldered into a brass plug and the plug forcibly screwed into a pipe-fitting, or where the pipes are cast iron, into a hole tapped into the pipe itself. For large stations, where connecting to underground pipes with bell and spigot joints, it is well to connect to several lengths, as the pipe joints may be of rather high resistance.

Where ground plates are used a No. 16 Stubbs' gauge copper plate, about 3 × 6 feet in size, with about 2 feet of crushed coke or charcoal, of pea size, both under and over it, would make a ground of sufficient capacity for a moderate-sized station, and would probably answer for the ordinary substation or bank of transformers. For a large central station, a plate with considerably more area might be necessary, depending upon the other underground connections available. The ground wire should be riveted to the plate in a number of places, and soldered for its whole length. Perhaps even better than a copper plate is a cast-iron plate with projecting forks, the idea of the fork being to distribute the connection to the ground over a fairly broad area, and to give a large surface contact. The ground wire can probably best be connected to such a cast-iron plate by soldering it into brass plugs screwed into holes tapped in the plate. In all cases, the joint between the plate and the ground wire should be painted with waterproof paint or some equivalent.

In the past few years, there has been much discussion of this question of grounding, but the general tendency is no doubt more and more in favor of grounding all circuits where so doing will protect life and will not introduce extremely hazardous conditions as regards fire. Companies and departments in charge of water works are urged to allow the attaching of ground wires to their piping systems in the full confidence that the integrity of such piping systems will not in any way be affected whatever may be the normal voltage. The following statement is taken from the explanatory notes of the Associated Factory Mutual Fire Insurance Companies:

If the primary and secondary coils of a transformer come into contact electrically, the high-voltage primary current may flow to the secondary system. If this should happen, the life of any one handling any part of the secondary system would be endangered, and fires would probably be started by arcs caused by breaking down of the insulation of the wires or fittings on the secondary system. If, however, the secondary coil is grounded, a breakdown in the transformer cannot cause a dangerous difference of potential between the secondary system and the ground, and only with certain unusual combinations of contacts between the primary and secondary wires outside of the transformers will this protection fail to prevent the voltage of the secondary system from being raised above its normal limit. To secure the full benefit of the ground connection, reliable primary fuses must be provided.

The *middle* of the secondary coil is the proper point to ground, as there is then only half the normal secondary voltage between either side and the ground, thus reducing the liability of a breakdown of insulation and also materially lessening the danger of fire if a breakdown does occur.

There is an objection to grounding the secondary on the other hand, for when this is done, the first breakdown of insulation may mean a short-circuit and a possible fire. With a system free from grounds, a breakdown must exist on each side of the system to cause a short circuit: with proper detectors the first can generally be found and remedied before the second occurs.

Grounding is, therefore, a choice of evils, but in many cases it is believed to be a lesser one than to risk getting the primary current on the secondary

system. This is especially true where the primary voltage is high, say 3,500 or over. For this reason it is advised that all transformers be so designed and connected that the middle point of the secondary coil can be reached if, at any future time, it should be desired to ground it.

After the transformer secondary has been properly grounded a test should be made, especially if the transformer is some distance from the building supplied, in order to determine if the protection expected from the ground connection at the transformer is really effective inside the building in question, and if not the connection should be extended to accomplish the desired

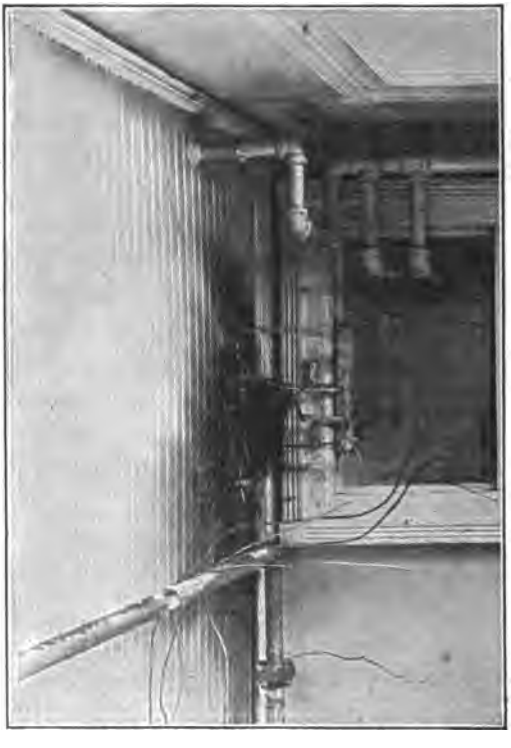


Fig. 54. Effect of Short-Circuit from Lighting Wires to Bell Circuit

result. Cases have been known where the effectiveness of a ground connection has been limited to a comparatively small area, due to the exact conditions of the earth in the neighborhood of the ground plate and between it and the point where the protection due to the grounding was desired. The entire ground connection should be carefully examined at least once a year.

INSIDE WORK

Under this heading are included the rules for wiring and appliances for light, heat, and power distribution and use. These cover

the most general cases of electrical installations as they relate to fire prevention and protection in buildings of all classes. The installation of wires and apparatus for signaling systems, such as electric bells (battery current bells), telegraphs, telephones, fire alarms, and the like, is not covered in the general rules for "Inside Work" since they usually present no hazard in themselves but only as they may become dangerous because of their liability to become crossed with light, heat, or power wires either outside or inside of buildings, Fig. 54.

WIRING SYSTEMS

The present approved methods of electrical work inside buildings in this country have been developed through many years of experience, beginning with the first applications of electricity for lighting buildings and gradually changing as the possible dangers became more generally recognized, and as improved means of guarding against them were devised. In this development the efforts of insurance and municipal authorities have been supplemented by an immense activity on the part of inventors and manufacturers in supplying new devices and materials. The net result has been on the one hand an elaboration of rules and an approach to a few standard systems of construction and on the other hand the production of an almost endless variety of materials available for electrical purposes. Methods and materials which at first seemed adequate have become obsolete after a few years' use. At present, however, few important changes appear to be in progress but in many minor details the development is still going on.

At first, electric wires were laid as seemed most convenient in floors, partitions, and over walls and ceilings, either in channels cut for them, in wood casings, or supported on wood cleats with almost no regard to protecting the wires from injury, or the adjacent combustible materials from being ignited by overheated wires or by arcs. Today, however, these earlier crude methods are wholly abandoned and it is generally conceded that the best protection against electrical fires lies in the adoption of the most approved methods even when the first cost of an installation is increased to some extent. Fig. 55 shows some defective wire joints as found in actual use.

In buildings of the better class, the electric installation is care-

fully considered in the plans, and provision is made for its safety as well as for its efficiency and economy. However, in cheaper buildings, and very often in small stores, apartments, and residences, the electrical work is left to be arranged as best it may and to be installed by careless workmen without expert supervision. In

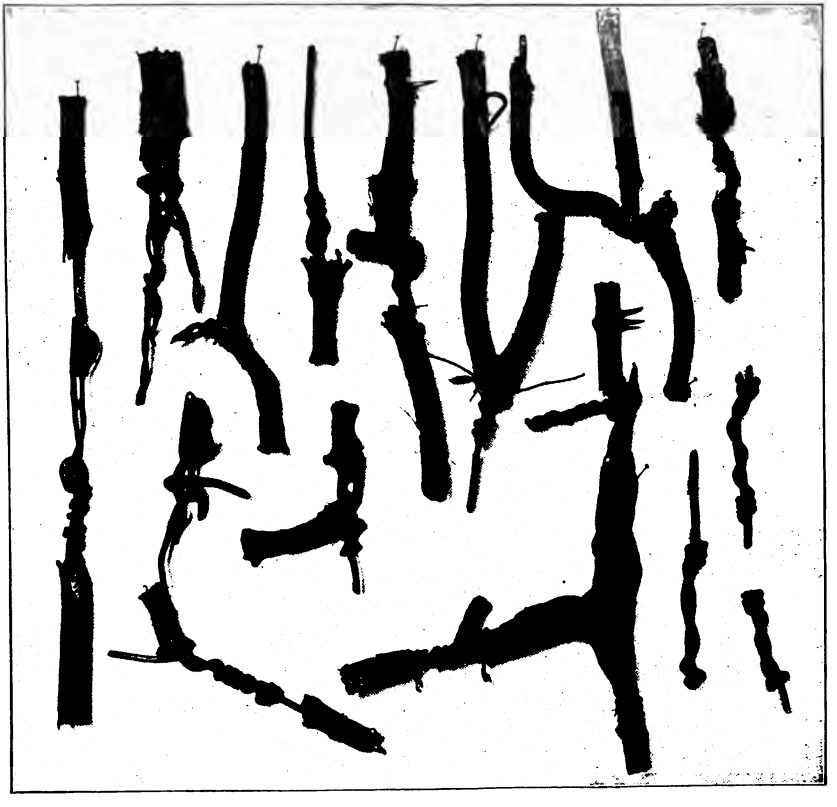


Fig. 55. Typical Defective Joints in Electric Installation

electrical matters as in most other affairs, cheap work is generally poor work, and deviation from the methods shown by experience to be reliable are usually prompted by a desire to save money at the expense of safety and permanence.

The method of bringing supply or "service" wires into buildings naturally demands first attention. Where street mains are underground the lines should, wherever possible, enter through the base-

ment or cellar walls, the lead-covered cables being carried through the foundations through tubes tightly sealed.

Where mains are overhead, the supply wires may enter either through the basement, being carried down the outside of the wall in iron conduit, or through some upper portion of the wall, though the former entrance is almost always preferable. Where transformers are used they may be on poles near the building or mounted on the outside wall in a substantial manner. An entrance through a roof, near a cornice or into little used or inaccessible attics or lofts, should be avoided. Where wires or cables pass through the outside walls there must be either iron conduit or insulating bushings sloping upward toward the inside, and the wires outside must have drip loops which will prevent moisture following along them into the wall. The fastenings of the wires to the building must be most substantial and good insulators must be provided for the supply wires. Fig. 56 shows the method where bushings are employed. If the entrance is made through conduit, the inner end of the conduit should always be extended to the service fuses. At the nearest accessible place in the building must be placed what are called the service fuses and the service switch. The switch is usually of the knife-blade pattern and must be such as to cut off all the wires. Single-pole switches must never be used as service switches. The purpose of service switches is to provide means for cutting off current for repairs or in case of fire or other accident. The service fuses should be placed between the service switch and the mains to the outside of the building. Their purpose is to protect all the wires inside the building from overloads, and they should be such as to melt or "blow" with current not much in excess of the normal full current likely to be taken by the entire installation which the service supplies.

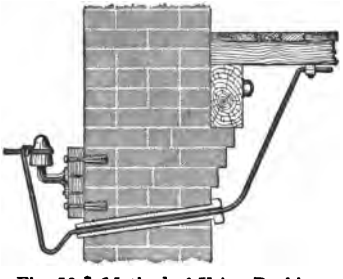


Fig. 56.* Method of Using Bushings

Service switches and fuses take many forms, from a pair of small "plug fuses" and knife switch on a porcelain base to quite elaborate switchboards which carry both these and other sub-fuses for the main circuits within the building. The same principle, how-

*Courtesy Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.

ever, applies to all; all wires must be protected, the service entrance must be accessible and fuses must be of proper capacity. From the service switch the lines usually extend through meters to distribution centers which are panels from which the several sub-circuits branch off to lamps or motors through the building. Fig. 57 shows such a center. There may be only one such center in a small installation, or in a larger one there may be a main distributing panel and numerous smaller ones at various places in the risk.

General Rules on Wires. *Size.* No wire smaller than No. 14 B. & S. gauge is allowed (except in fixtures and for pendant or flexible cord) since no smaller size has both the conductivity and also sufficient mechanical strength to stand the strains of installation and use.

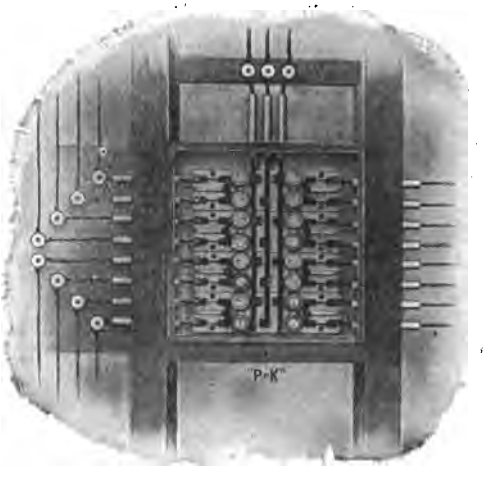


Fig. 57. Distributing Panel for Lighting Circuit

Joints and Splices. All joints and splices must be made both mechanically and electrically secure *and then be soldered* except when one of the very few approved splicing devices is used. For general wiring, the underwriters have never found any equivalent for *good* soldered joints when all the possible effects of corrosion, alternate heating and cooling, vibration, and mechanical strains are considered. The neatness and thoroughness of the soldered joints are two of the best general indications of the excellence of the workmanship on any job. After being soldered wire joints must be covered with an insulation equal to that at other places on the conductors. This is usually done by winding the joints with a good pure rubber tape over which is wound a "friction tape" of fabric impregnated with a compound.

Wires in Walls, Floors, etc. Wires must always be separated from walls, floors, timbers, and partitions by non-combustible, non-absorptive, insulating tubes such as glass or porcelain and must be

kept free from all contacts with pipes or any conducting material. This general rule is established without any reference to the insulation which is on the wires themselves, the idea being that the insulation of the conductors from each other and from other conducting materials must be sufficient to furnish the necessary protection in case the wire coverings are defective or become injured in any way. This principle does not, however, prevent the wires being drawn into metal conduits which are specially designed as wire raceways, nor can it apply to fixtures in which the wires must be in the metal stems

Fig. 58.* Approved Overhead Wiring

and arms. For such cases special rules are established. Fig. 58 shows a good example of overhead wiring in which an iron pipe may be seen protecting wires up the post, while the wires on ceiling and around beams are very well arranged and supported.

In damp or wet places, the relative arrangement of pipes and wires should be such that the wires cannot touch the pipes and so that water cannot drop from the pipes on the wires. The subject of electrical work in damp places will be considered in another place.

Carrying Capacity. The Code prescribes the maximum current which shall be carried on copper wires of different sizes. This table, which has been recently somewhat revised, was originally

* *Courtesy Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.*

based upon an elaborate series of careful experiments. Table III gives the revised figures for rubber-covered wires, and for all types of wire insulation such as slow-burning and weatherproof braids.

The table for rubber-covered wires is lower than the other because high temperatures such as might result from a wire carrying too much current have a harmful effect on the insulating properties of rubber. The table is for indoor work only. It is stated that for any given size of wire, a current about three times as great as that given in Table III will cause all ordinary insulations to smoke. The table does not consider the question of *drop* as it is called. Thus in Fig. 59, suppose D is a dynamo supplying current to M, a motor 250 feet away from it, and suppose the motor requires 90 amperes at 220 volts. From Table III it is seen that No. 2 wire could be used. But some *power* is lost in driving the current through the 500 feet of line wire and, if the wire is small, its resistance will be large and so more power will be "lost on the line wires." The part of the dynamo voltage required to drive the working current over the supply wires is called the "drop." Suppose it is prescribed that the drop shall not be over 1 per cent of the total voltage. One per cent of 220 volts is 2.2 volts. The current in the line equals the voltage to force the current over the line divided by the ohms resistance of the line.

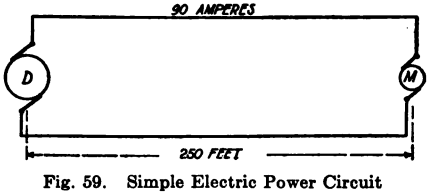


Fig. 59. Simple Electric Power Circuit

In this case $90 = \frac{2.2}{\text{resistance}}$, or resistance of the 500 feet of wire must not be more than $\frac{2.2}{90}$ ohms or .024 ohms. From a suitable wire table it will be found that a No. 0000 wire will be required. Thus the necessity of keeping the loss of power low on the line may necessitate the use of a larger wire than would be needed for safety under the underwriters' rules.

Constant-Current Systems. The nature of these has already been explained on page 13. Such systems are used nowadays almost exclusively for street lighting with arc lamps and the voltage runs

TABLE III

Carrying Capacity of Wires

B. & S. G.	Rubber Insulation Amperes	Other Insulations Amperes	Circular Mils
18	3	5	1,624
16	6	10	2,583
14	15	20	4,107
12	20	25	6,530
10	25	30	10,380
8	35	50	16,510
6	50	70	26,250
5	55	80	33,100
4	70	90	41,740
3	80	100	52,630
2	90	125	66,370
1	100	150	83,690
0	125	200	105,500
00	150	225	133,100
000	175	275	167,800
0000	225	325	211,600
Circular Mils			
200,000	200	300	
300,000	275	400	
400,000	325	500	
500,000	400	600	
600,000	450	680	
700,000	500	760	
800,000	550	840	
900,000	600	920	
1,000,000	650	1,000	
1,100,000	690	1,080	
1,200,000	730	1,150	
1,300,000	770	1,220	
1,400,000	810	1,290	
1,500,000	850	1,360	
1,600,000	890	1,430	
1,700,000	930	1,490	
1,800,000	970	1,550	
1,900,000	1,010	1,610	
2,000,000	1,050	1,670	

from 2,000 to 3,300 volts. The arc lamps on such circuits are arranged so that each line has enough lamps in series to use the available dynamo or transformer voltage allowing the necessary margin for regulation.

The high voltages generally employed, call for the very best insulation and only rubber-covered wire should be used; all wires in buildings must be in plain sight and never encased. The bringing of such circuits into buildings is not very general and arc lamps designed to be connected in multiple on ordinary low-voltage circuits are much to be preferred.

There are special rules for series arc-lamp wiring in buildings which cover the method of bringing supply wires through the walls, provision for a special form of switch at points where the lines enter and leave the building, requirement for 1 inch separation between wires and the surfaces over which they pass and 8 inches from each other and extra protection of all wires by running boards or guard strips. The service switch required on constant-current systems must be a *double-contact* switch, that is, it must be so arranged as to first place a cross connection or short-circuit on the lines into the building and then disconnect these lines from the supply altogether. This leaves the circuit unbroken, but cut out of the building. An attempt to actually break the circuit would be sure to cause a very destructive arc. Series arc lamps must be carefully isolated from all inflammable stuff and unless they are of the "enclosed arc" type must be provided with screens and nets to prevent the escape of sparks from the carbon or melted copper. All connections must be made in a most reliable manner and in all series arc work it must be remembered that the voltage across any break in the circuit is very high and will cause very severe arcing.

Incandescent lamps are not generally connected to series circuits since their use involves an automatic cut-out at each lamp which will shunt the current around the lamp in case the lamp becomes loose or its filament breaks. These devices are expensive, difficult to keep in order and generally undesirable. Formerly, combinations of incandescent lamps on series circuits were used, consisting of groups of lamps in series or in multiple, but these arrangements are not now in use and are forbidden in the rules. It is evident that incandescent lamps on series circuits should never be

allowed on gas fixtures since an arc to the grounded gas pipe would be very severe and would be liable to burn through the pipe and ignite the escaping gas.

Constant-Potential Systems. The character of these systems has been explained on page 12. Almost all systems for light and power in buildings of all sorts are of this type. The most common are 110-volt two-wire direct-current systems; three-wire systems with 220 volts between outside wires and 110 volts between the neutral and either outer wire; 500- to 600-volt d. c. street and elevated railroad systems with "ground return"; 440- to 600-volt a.c. systems for motors. In addition there are 1,100-, 2,200-, and 3,300-volt a. c. power circuits and the so-called a. c. transmission lines at all voltages from 1,000 up to 80,000 or 100,000 volts. While occasionally a. c. motors are made for direct operation at 1,100 or 2,200 volts, in general for voltages above 600 volts, alternating-current transmission lines are employed which are connected to transformers at the factories or mills where the power is used and which "step-down" the voltage to 440 volts or some other voltage which can conveniently be used in the motors and for lighting purposes. Both the primary and secondary circuits in this case are constant potential systems.

In street railway work large machines called rotary converters are employed which are driven by the high-voltage alternating current from transformers connected to the transmission lines and which deliver direct current at about 600 volts to the trolley system. Such rotary converters are usually placed in substations so located as to conveniently and economically supply the different sections of a city. A similar practice is followed in cities where direct current is to be furnished for general lighting and power, and the original generating station is more or less remote. Such substations come under the same rules as generating or dynamo stations.

All so-called isolated plants, that is, plants in individual factories or large buildings, are constant-potential systems also. In the underwriters' rules constant-potential systems are subdivided into *low potential systems* up to 550 volts; *high-potential systems* 550 to 3,500 volts; and *extra-high-potential systems* over 3,500 volts. Of these the low-potential systems are of most importance since they include the very great majority of equipments for using electricity in buildings for light, heat, and power.

GENERAL INSTALLATION RULES FOR CONTROLLING AND PROTECTING DEVICES

Switches, fuses, and circuit breakers may all be described as arcing devices, that is, their operation always produces an arc. This arc may be small or large but it is impossible to break a circuit-carrying current without some arc even if it is so small that it is a mere spark. The duration and intensity of an arc depends upon the strength and voltage of the current, the rapidity with which the gap in the circuit is widened, and the design and condition of the arcing device, switch or fuse. Dust or inflammable gases may be ignited by an arc of sufficient intensity. No arcing device, therefore, should be placed near easily ignitible stuff, or exposed to inflammable gases, or dust, or flyings of any combustible material. When so exposed, as in flour mills, textile mills, etc., all switches and fuses should be enclosed in dust-tight boxes or cabinets. Open-link fuses are especially liable to flash violently and throw out molten metal and they must, therefore, be given special attention, and should never be installed outside of proper cabinets except on switchboards in fireproof rooms, such as engine rooms, generating stations, or where they will be under constant and expert supervision. Even in ordinary rooms, houses, stores, or factories, where there is no dust or combustible flyings in the air, it is much better to have all knife switches and all fuses placed in cabinets to prevent accidental short-circuits, caused by laying a metal object across the exposed parts.

Switches immersed in oil are in common use for large currents and are quite safe as regards arcing, though the oil involves a certain hazard since it is combustible.

It should be remembered that any switch or circuit breaker which is automatic, that is, which is not operated by hand by a person at the actual device itself, requires better protection since in case of failure the arcing may be severe and no one may be at hand to take the needful steps to prevent its starting a fire. Such automatic current-breaking devices including time-switches worked by clocks, sign flashers, and the like, should always be enclosed in very substantial non-combustible cases or cabinets of ample size and so arranged that they are not liable to be left open.

Switches. The general requirements for service switches have already been discussed. While it is true that the service switch

and a switch for every motor are the only ones that are absolutely required by the rules, still convenience and economy of operation naturally call for a number of switches in practically every installation, and the correct placing of them becomes, therefore, a matter of importance. The description of some of the very numerous types of switches will be given later in this book, but we consider here the general rules for installing all types.

As a general principle, switches must always be placed in dry, accessible places and it is well to group them together so far as possible for the reason that this will often reduce the amount of wiring and also render it easier to use them in case of need.

Knife Switches. Knife switches consist of copper blades, one for each pole, hinged at one end to copper clips or posts and closing at the other into other clips. Where such a switch is made to close

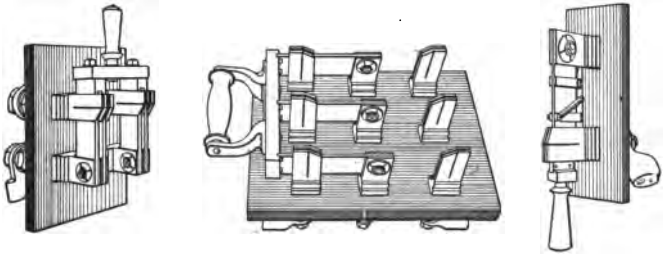


Fig. 60. Single, Double, and Triple Pole Knife Switches

into clips at only one side of the hinge end it is called a *single-throw* switch and where the blades can be thrown into clips at either side of the hinge it is called a *double-throw* switch. Single-throw switches must always be installed so that gravity will tend to open rather than close them since otherwise they might fall and, by only partly closing, cause arcs and burning. Double-throw switches may be installed so that the throw is either vertical or horizontal as preferred. Fig. 60 shows a double-pole single-throw switch and a triple-pole double-throw switch correctly placed and a single-pole single-throw switch wrongly placed.

Whenever practicable, knife switches should be so wired that the blades will be *dead* when the switch is open as this leaves less exposed live metal and also makes it easier and safer to make any repairs or adjustments of the switch blades and hinges. In Fig. 61 if the supply wires (from the service or dynamo) enter at the top

and the lamps are connected from the bottom of the switch, the blades will be *dead* when the switch is open. If the arrangement is reversed, the switch blades will be connected to live wires all the time, whether the switch is open or closed. The illustration also shows an excellent type of cast-iron cabinet for such a switch combination.

Fig. 61. Approved Metal Switch Box

Surface Snap Switches. These are the common porcelain base switches, usually round in shape and having metal covers with the operating handle at the center. They are commonly mounted on side walls and the wires are brought into them from the back. It is not possible to fasten them very securely to a lath-and-plaster wall unless some block is provided for the screws to be driven into. For this reason, wherever possible, at all switch or fixture outlets, a $\frac{7}{8}$-inch block must be fastened between studs or floor timbers flush with the back of lathing to hold tubes, and to support switches or fixtures. When this cannot be done, wood base blocks, not less than $\frac{3}{4}$ inch in thickness, securely screwed to lathing, must be provided for switches, and also for fixtures which are not attached to gas pipes or conduit. Figs. 62 and 63 show these blocks with the wires brought through them and through the lath and plaster in short lengths of flexible tubing. The switches can thus be firmly screwed to the blocks and the wires connected to them.

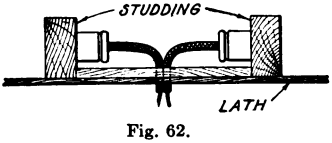


Fig. 62.

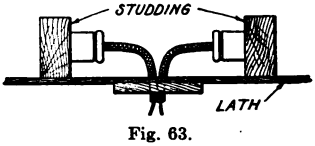


Fig. 63.

Proper Arrangement of Wires Passing through Lath-and-Plaster Partition

If snap switches are used with exposed wiring on cleats, there must be a porcelain sub-base under each switch so made that the wires will be kept $\frac{1}{2}$ inch from the surface wired over. A similar

sub-base must be used where such a switch is used with wood molding, but in this case it may be of hard wood instead of porcelain. Figs. 64 and 65 show how this is done.

Flush Switches. These are made to be inserted into walls so that only the operating push buttons or handle will extend out beyond the surface, and are now in very general use. Inasmuch as their operating parts are concealed in the wall they should invariably be set into small steel boxes through the back of which the wires may enter either through lengths of flexible tubing or through iron conduit. The same requirement applies to all small fittings such as receptacles from which flexible cords are run to heaters and other portable devices. Fig. 66 is a sketch of such a switch box set into a lath-and-plaster wall. The sketch shows the box as it would appear from the back of the wall.

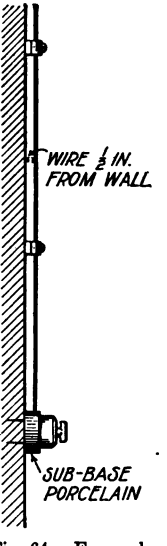


Fig. 64. Exposed Wiring on Cleats

Where it is desired to control the same electric lamps from either of two switches at different places, what are called *three-way* switches are installed. These are chiefly used in residences, as for the control of hall lights from either upstairs or downstairs. Under the rules these are classed as single-pole switches and are preferably wired so that only one main of the circuit is carried to either switch. Three-way switches are usually of the common round-surface porcelain-base type or push-button wall variety. Fig. 67 gives a diagram of the way to connect them.

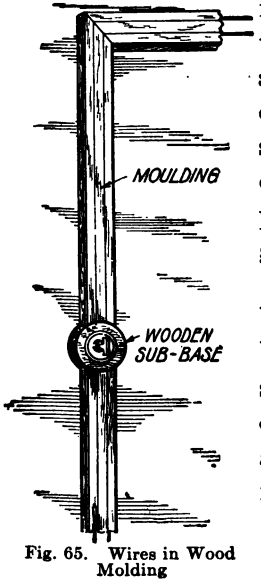


Fig. 65. Wires in Wood Molding

Fuses and Circuit Breakers. These may be compared with "safety valves" on steam boilers, that is to say, they are primarily designed to act in case of an improper condition of affairs and prevent by their automatic action any serious trouble resulting. Although this is the purpose of fuses and overload circuit breakers, it is altogether too common for users of electric current to misuse them, and so de-

stroy the protection intended. It is evident that a fuse which is so large that it will not melt until a current passes through it which is far too large to be safely carried by the wires or other parts of the circuit, is worthless. The fusible part of a fuse is usually a strip or wire of soft lead or zinc of such size that if any considerable current over that for which it is designed passes through it, it will melt off and so open the circuit. Whenever a fuse of the proper size for its circuit *blows* or *melts*, the first thing to be done is to seek out the cause, for the operation of the fuse is *proof* that there is, or has been, something wrong. Thus if in a house a lighting-circuit is properly protected by 6 ampere fuses and these fuses blow, one may be sure that more than 6 amperes, and, therefore, *more than a safe current* has, for some reason, traversed the wires for a time long enough to melt the small fuse strip. Now, unless this excess of current was due to some momentary accident, known and recognized as such, the same condition that once allowed the unduly large current to flow probably still exists, and until this trouble is sought out and remedied, the same unsafe condition exists. It is, therefore, very unwise to replace the blown fuses with some of larger current-carrying capacity, for this is merely reducing the protection without removing the source of danger.

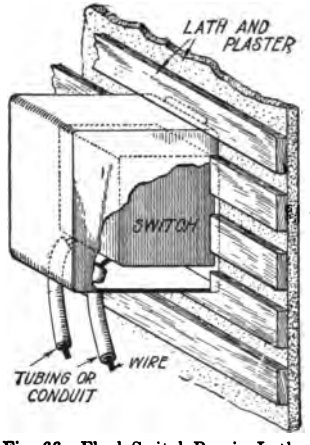


Fig. 66. Flush Switch Box in Lath-and-Plaster Partition

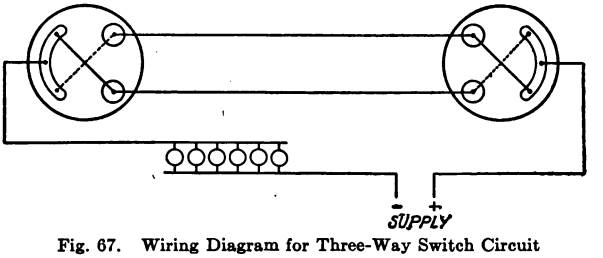


Fig. 67. Wiring Diagram for Three-Way Switch Circuit

Still worse is it to replace blown fuses by fuses which have been filled up with metal, or across, or through which, extra metal strips have been fastened in a misguided attempt to keep the fuses from

blowing again. One might as reasonably tie down a steam boiler's safety valve. These principles when thus stated appear very elementary and self-evident and yet the misuse and abuse of fuses is, perhaps, the commonest fault observed in the maintenance of electric installations. The only reason that disaster does not always follow ignorant or culpable misuse of fuses, is to be found in the fact that wires and other parts of the system are installed with a fairly large margin of safety. This does not, of course, in any degree justify over-fusing circuits or tampering with fuses or other safeguards, and insurance inspectors should not tolerate any deviation from standard rules for the protection of circuits or fail to demand the use of only approved protective devices of proper rating for every circuit. Fig. 68 shows some fuses which have been "doctored" in ways unfortunately all too common.

The following excellent statement is taken from the book of rules of the Associated Factory Mutual Companies:

Fig. 68. Typical Examples of "Doctored" Fuses

Specifications for fuses require that they shall be rated at a certain per cent of the maximum current which they will carry indefinitely, as follows: link fuses 80 per cent and enclosed fuses 90 per cent. The margin thus provided between the rating of the fuse and its actual melting point will permit the ordinary fluctuations in current without opening the circuit. If fuses selected to conform to the above rule are not large enough to carry the load, it is evident that the wires also are overloaded, and either the load should be diminished or the size of the wire increased.

Circuit breakers are so sensitive that it is often necessary to set them much above the ordinary current to keep them from being constantly opened by momentary rises in the current, such as might be caused by starting a motor or by a rise in the voltage of the dynamo due to a sudden decrease of load.

When this is the case, a fuse may be necessary to protect the wire from a steady current above the safe carrying capacity of the wire but below the point at which the circuit breaker is set to open. The fuse requires a little time to heat, and so does not melt with the momentary rises of current which would open the circuit breaker if it were set as low as it would have to be if the fuses were not provided.

It has already been pointed out that "service entrances" must be fused, that is, there must be a fuse in each wire where the current supply is brought into a building. An exception is made in the case of three-wire (not *three-phase* a. c., however), systems. In these the fuse may be omitted in the neutral wire, provided this wire is of equal carrying capacity with the outside wires and is reliably grounded, since in such a three-wire system the neutral wire cannot under any condition carry more current than either of the outside wires; the fact that it is grounded adds a certain safety, because it is especially desirable that the neutral should not be opened unless the

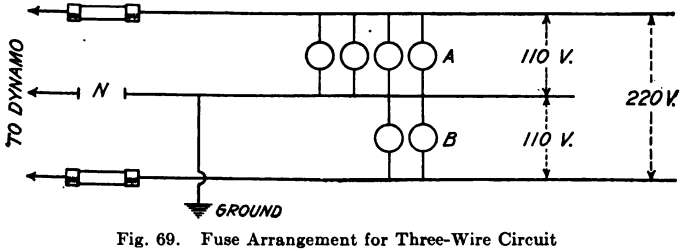


Fig. 69. Fuse Arrangement for Three-Wire Circuit

outside wires are also opened, as might occur if a neutral fuse alone blew, or was removed without the others also opening. Fig. 69 illustrates this point. When the fuse in the neutral at *N* is in place, lamps *A* can have only 110 volts across them and lamps *B* the same, but if the fuse *N* is removed, the group *A* will be in series with the group *B* across the 220 volts of the outside wires, and as there are 4 lamps at *A* and only 2 at *B*, the resistance and volts *drop* across *A* will be only one-half the resistance and drop across *B*. Thus *A* will get only one-third of 220 volts or 73.3 volts, and *B* will get 146.7 volts. The lamps *B* will thus burn *over bright* or even burn out, and those in *A* will be dim. Of course, if there were the same number of lamps at *A* as at *B*, it would make no difference whether the neutral wire were open or not, but when the system is *unbalanced* as in Fig. 69 it is better to avoid having the neutral opened and, therefore,

the fuse in it is often omitted, and the wire carried through unbroken.

Beyond the service entrance fuses and switch, the circuits are usually divided; thus in a house several circuits of smaller wire will lead to the lights on the different floors, or in a larger building or a factory, sub-mains will be carried up to the distributing centers through the building from which in turn smaller wires will branch out. The proper proportioning of these cables and wires for the economical distribution of current is a problem for the electrical engineer. The point to be noted here is that fuses or breakers must be placed at every point where a change is made in the size of wire unless the fuse next back will also protect the smaller wire. The rated capacity of fuses must not exceed the allowable carrying capacity

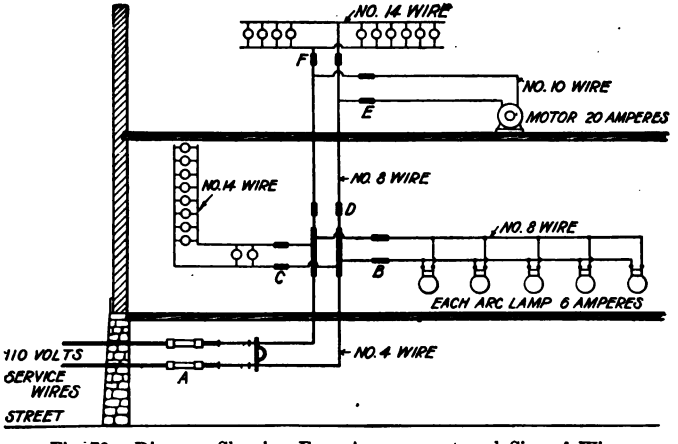


Fig. 70. Diagram Showing Fuse Arrangement and Size of Wire for Typical Lighting and Power Circuit

of the wire as given on page 65, and circuit breakers must not be set more than 30 per cent above the capacity of the wire unless a fuse is also used, when they may be set 100 per cent higher. Fig. 70 shows the sizes of wire and the fuse arrangement for a typical case. The arc lamps require 30 amperes, the 20 incandescent lamps 10 amperes, and the motor has a full load current of 20 amperes. The motor, however, must have leads for 25 per cent above full load current or 25 amperes or No. 10 wire. Allowing 60 amperes for the total normal current the service fuses at *A* might be 60 amperes and the wires next beyond them No. 4. The other wire sizes are shown and the fuses would have to be placed as shown and have the following

ratings: *B*, 30 amperes; *C*, 10 amperes; *D*, 30 amperes; *E*, 20 amperes; and *F*, 10 amperes. The 10-ampere fuses are required at *C* and *F*, because by a special rule mentioned below this is the limit for fuses for branch circuits at 110 volts supplying incandescent lamps. A pair of fuses is also required for *each* arc lamp and these would in the case shown usually be of a 10-ampere rating. If circuit breakers were substituted for the motor fuses at *E* they should be set to open at not over 30 per cent above the capacity of No. 10 wire or about 31 amperes.

It will frequently be found necessary to provide cut-outs where taps are taken from large mains. In such cases, if the clamps on the cut-outs are not sufficiently large and strong to give a firm and secure connection, a short length of smaller wire may be soldered to the main wire and then carried direct to the cut-out, which should be located as near as possible to the point of connection with the mains. Special care should be taken to guard these leads from accident as they may not be properly protected by the fuses in the main circuit.

Fuses are always installed in pairs (or sets of 3 on three-wire circuits), so that each side of the circuit is fused for the reason that a "ground" or "cross" might occur so as to cause a large current to flow over a path not including any fuse. Furthermore, fusing both sides gives a much greater factor of safety and insures protection under all conditions.

In installing incandescent lamps, fuses must be so placed that no set of lamps requiring more than 660-watts power will be dependent on a single pair of fuses. Some city rules state this in terms regulating lamp sockets or receptacles, and limit the number of such sockets since this amounts to about the same thing. The purpose of this rule is to secure such a subdivision of the fuses that no very large currents can flow for any long time over any part of the small wiring without opening a fuse and thus the effects of a short-circuit or other accident will be very much minimized. Suppose we had a long line of No. 10 wire protected by 25 ampere fuses on a 110-volt circuit, and 50 incandescent lamps in multiple on this line with no other fuses. Suppose also that only one of the lamps were burning. Now if this lamp were hung on a flexible cord and a "short-circuit" occurred on the cord or in the lamp socket, we should have to wait until the short-circuit became severe enough to allow about 30

amperes of current to flow before the 25-ampere fuses would open. (All fuses will carry, for a short time, more than their rated currents.) But 30 amperes at 110 volts may cause an arc quite intense enough to set fire to the cord or cause molten metal to drop from the overheated socket. If the lamps were on a branch circuit of No. 14 wire protected by 10-ampere fuses, these fuses would probably melt before serious harm were done. Thus it may be seen that it is wise to subdivide the lamp circuits and protect each circuit with small fuses. In exposed wiring in large mills an exception is made permitting incandescent-lamp circuits with 25-ampere fuses to be used provided *each lamp* is protected by a very small fuse placed in a ceiling rosette. This is allowed to prevent running an excessive amount of wiring through large rooms where the crowded wires might be themselves a source of danger. It was formerly the custom to place small fuses in the canopies of fixtures or ceilings and side walls but they were always troublesome and dangerous to an extent that did not offset the slight extra protection they afforded and all such "bug" fuses have long been forbidden.

Enclosed fuses, plug and cartridge, are allowed by the Code rules to be installed without cabinets except in dusty or linty places but some municipal ordinances require *all* fuses to be in cabinets. While this is safer, there would be a tendency to use the open-link lead fuse everywhere if cabinets were universally required since they are much cheaper than enclosed fuses, and this is a tendency not to be encouraged. If proper locations are chosen for enclosed fuses and if only approved fuses are used, there is little hazard under ordinary conditions. Enclosed fuses either of the cartridge or the plug type and of makes having the underwriters' approval will open the circuits for which they are rated with practically no explosive action and without emitting flame or molten metal even on heavy short-circuits. Even so, however, they should never be placed near combustible material.

Electric Heaters. Under this heading are included all devices in which use is made of the heat developed by the current (usually by causing it to pass through coils of wire). These are electric pressing irons, air and water heaters, toilet articles, such as curling irons, cooking devices of all sorts, and a vast and constantly increasing variety of domestic and industrial appliances. All these present

the same hazards as other heaters of equal capacity, except that the dangers of open gas flames and of matches are eliminated, and they all require the same precautions in use and in their installation. Each should be protected by fuses on the device, or preferably in the branch circuits, and must be controlled by separate switches or plug connectors so made as to indicate whether the current is "on" or "off." These must be double-pole switches if more than 660 watts of energy is required. In general, such heaters should never be "built in" but should be in plain sight. However, for many industrial purposes electric heaters are constructed as parts of tools or machines and when well made and used with due care are not more hazardous than other methods of heating.

Portable heaters are in general more dangerous than stationary ones since the latter may be safeguarded by suitable heat-resisting material placed between the device and its surroundings, such as

Fig. 71. Effects of Careless Use of the Electric Iron

sheets of tin or steel with an air space between them or by alternate layers of sheet steel and asbestos with a similar air space.

The electric flatiron is perhaps the cause of more trouble and danger from fire than any other form of heater. The temperature of the iron required for ironing damp fabrics is necessarily high (at least 500° F. is common) and if the iron is left with current *on* and is not in use it will become red-hot in from ten to twenty minutes. If it has been left on a table or on clothing a fire is almost inevitable. Fig. 71 shows a cloth-covered board burned by electric irons. Few irons have any automatic cut-off to guard against such an accident and the fact that many such irons are used by persons not familiar with the possible danger, makes these devices rather hazardous.

It is often desirable to connect in multiple with the heaters and

between the heater and the switch controlling same, an incandescent lamp of low candle power, as it shows at a glance whether or not the switch is open, and tends to prevent it being left closed through oversight. An approved stand, of a pattern such that the iron may be safely left on it even with the current on, should be used with every electric pressing-iron. The ordinary plain iron stand for cast flatirons is not adequate as it will become hot enough to set fire to a table. It should be remembered that stove-heated irons get cooler when taken from the stove, while an electric iron will get hotter and hotter if left connected to the circuit and not used. Fig. 72 shows an iron properly installed with indicating switch, pilot lamp, and stand.

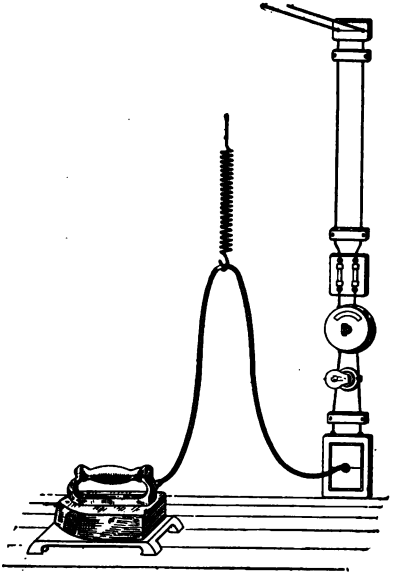


Fig. 72. Properly Installed Electric Iron Circuit

Portable heaters, if they require over 250 watts, should be furnished with approved "heater cord" which consists of stranded copper conductors with a thin rubber and a thick asbestos yarn covering over each with a good braid over all. In factories and shops where a large number of flatirons or rather portable electric heaters are used, the circuits leading to them should be so arranged and provided with switches that any department or tier of benches can be cut off when not in use and pilot lamps in conspicuous places should be provided to call attention to the fact that the circuit is closed to the heaters. Domestic cooking devices electrically heated, are, in general, fairly safe as made by well-known manufacturers, and are preferable from the viewpoint of fire hazard to similar appliances heated by gas or by alcohol lamps.

The use of flatirons or other heaters on ordinary lighting circuits is undesirable since they often require more current than can be taken through the proper fuses for such lamp circuits. It is very desirable that special circuits be run of large wire properly fused and with large capacity fittings and that all heating and small power devices such

as washing and vacuum cleaning machines be supplied from such special circuits. The ordinary wall or ceiling fixtures and the lamp sockets attached are very ill suited for connecting portable heaters because of their lack of current-carrying capacity; and, too, because they are not mechanically strong enough to withstand the comparatively rough usage to which such connections are inevitably subjected.

Fig. 73. Punctures in Gas Pipes from Short-Circuits

FIXTURES AND FIXTURE WIRING

Fixture Details. Electric fixtures are of two types known as straight electric and combination, the former carrying only electric lamps and the other having both electric and gas lights. The chief parts of a fixture are the canopy at ceiling or wall, the stem, the body, the arms, and the sockets. Most fixtures consist of pipes, often of small size, which are threaded into special castings in the body or central ball with arms branching from the body.

In straight electric fixtures the wires are usually drawn through the pipes, but in combination fixtures the gas runs in the pipes and the wires lie along the outside of the pipes between them and an outer casing or are drawn through cored holes in cast-brass arms. The necessarily small spaces and channels for wires in fixtures and the slight amount of insulation which the wires can carry, require very careful work in order that the best conditions possible may be maintained. The pipes in which wires are drawn should

be carefully reamed at ends and all sharp angles, burrs, and corners on which wires may be injured should be carefully rounded off. These details should be attended to by the fixture maker but are often neglected, resulting in such accidents as are shown in Fig. 73, where the current has burned holes through the gas pipe and ignited the gas. Nothing but rubber-covered wire having a rubber wall, and no wire smaller than No. 18 B. & S. gauge, should be used. Stranded wire is preferable to solid wire. A rubber insulation $\frac{1}{64}$-inch thick is permitted on No. 18 wire for fixtures, but all No. 16 wire and all flexible cord if used for fixture work should have at least $\frac{1}{64}$-inch wall. Fixtures are not allowed on circuits of over 300 volts.

Insulating Joint. On lath-and-plaster ceilings and walls where steel outlet boxes are not used, fixtures are usually fastened to some form of "crowfoot," a small tripod casting into which the stem of the fixture is screwed. Combination fixtures are screwed on the projecting nipple of the gas pipe. When fixtures are thus supported on gas pipes or when they are attached to any grounded metal work of a building or are on walls or ceilings of plaster on metal lathing, an approved "insulating joint" must be inserted between the fixture and its support. An insulating joint is a coupling, the two ends of which are reliably insulated from each other by some substance, such as mica. For combination fixtures there is a hole for the gas through the center of the joint. Such joints are required to be made of materials which will not be affected by the gas; no soft rubber is allowable and they must be capable of withstanding a voltage test of 4,000 volts a. c. between the two ends. Such insulation is required because the fixture wire is necessarily poorly insulated and liable to permit the conductors to become "grounded" on the fixture at one or more points. The insulating joint prevents such a failure in the fixture from causing current to flow to the earth in case the circuit is either purposely or accidentally grounded at other places. It also prevents voltage sufficient to puncture the fixture wiring from arcing across broken insulation to the fixture and so to the ground.

Canopy Insulators. Since the canopy or bell covering the base of the fixture at the ceiling or wall is in electrical connection with the fixture stem, it also must be insulated at its upper edge from the wall wherever an insulating joint is required. Canopy insulators take the form of molded rings of composition, fiber rings riveted to

the canopy edge or insulating linings and flanges of micanite or other suitable material. Fig. 74 shows a correctly mounted combination fixture with insulating joint and canopy insulator. The cut also shows the pieces of flexible tubing in which the wires are separately encased from the last porcelain support, through the ceiling and to a point below the insulating joint. *B* in the figure is a piece of insulating tubing which should be placed about the gas pipe above the insulating joint. In case the wires were in steel conduit a steel outlet box would be placed in the ceiling, the gas pipe would enter through a central hole in the back and the conduit through another hole at one side. In such cases the flexible tubes would not be used but the canopy insulator and the insulating joint would still be required. Most trouble from fixtures occurs in the canopy from poorly made wire joints and crowded or jammed wires which gradually give way until finally an arc is formed and the wire coverings are ignited, Fig. 75. Canopies are often made too shallow and too small and workmen are often careless in connecting fixtures.

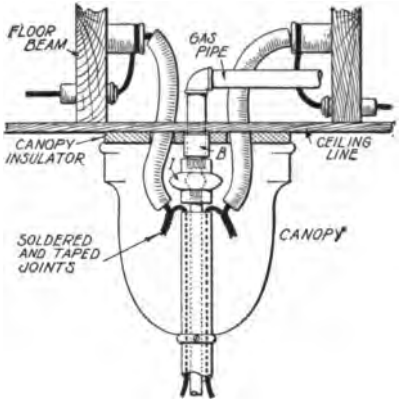


Fig. 74. Correctly Mounted Combination Fixture

Sockets and Receptacles. These are the devices into which incandescent lamps are put and are today made in a great variety of forms. The most common is the familiar brass shell socket either with a key switch or keyless, screwed on the ends of fixture arms or hung on flexible cords. Where a lamp holder is desired to be fastened rigidly to walls or ceilings, receptacles are used and this in general constitutes the distinction between receptacles and sockets. For outdoor use or in damp places weatherproof sockets or receptacles should be used. These usually have porcelain or composition outer shells, with connecting wires sealed in or with some form of encased terminal so placed and covered as to keep moisture from exterior and interior.

It is good practice to use only porcelain sockets in locations where a person might touch them while at the same time in contact

in any way with any grounded metal work. Thus in bath rooms if a person attempted to turn on a lamp by means of the key of a brass covered socket while at the same time he was touching a water pipe or faucet, he might receive a painful or dangerous shock if any portion of the electric circuit were grounded. While such a shock would not be given, if everything were in proper condition, still there are

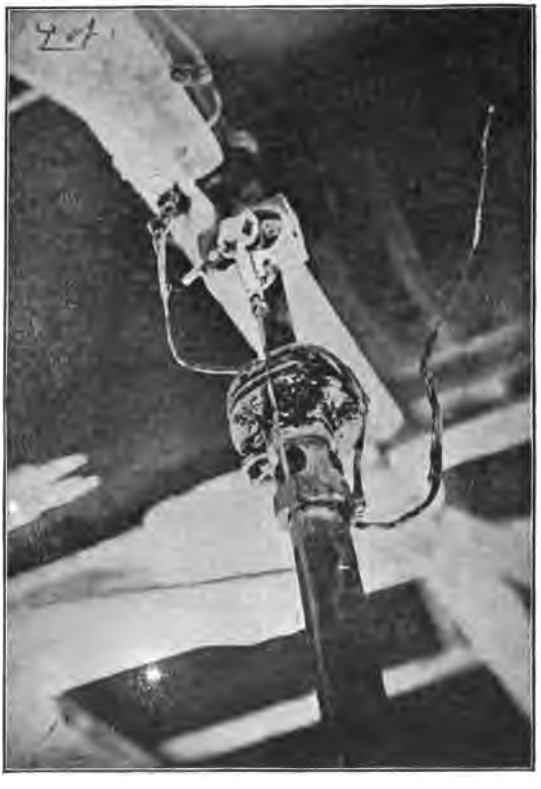


Fig. 75. Result of Defective Fixture Insulating Joint

numerous instances where persons have been killed and it is certainly wise to prevent even the chance of such an accident by either using all porcelain sockets or by putting the sockets out of reach, and controlling the lamps by means of a switch on a side wall. This practice is especially to be commended where the lamps are supplied with a. c. transformers the primaries of which are supplied by circuits

of voltages of 1,100, 2,200, or higher values. The voltages of 110 or even 220 either d. c. or a. c., which are almost universally used for incandescent lighting indoors, are not of themselves at all liable to injure persons, but if there is a fault in the transformer the high primary voltage may get into the house over the secondary lines and such a circuit will then be distinctly dangerous to life.

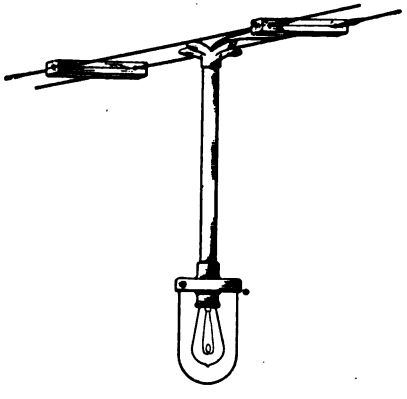


Fig. 76. Enclosed Incandescent Lamp as Precaution Against Explosive Vapor

In rooms where inflammable gases may be present, as the result of some manufacturing process or otherwise, the incandescent lamp and its socket must be enclosed in a vapor-tight globe and supported on a pipe hanger, wired with approved rubber-covered No. 14 wire soldered directly to the circuit wires. Even the minute spark caused by breaking a 16-candle-power lamp has been known to set fire to vapors such as gasoline and air in the proper mixture and the reason for taking every precaution against sparks where such vapors exist, becomes very apparent. Fig. 76 shows a lamp so enclosed and supported.

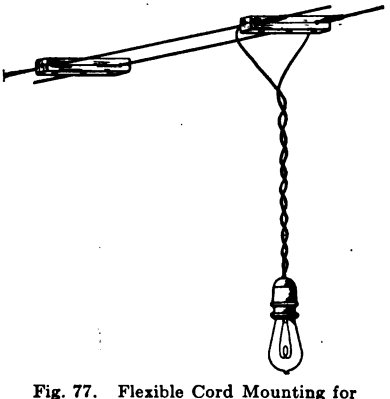


Fig. 77. Flexible Cord Mounting for Incandescent Lamp

In damp or wet places weatherproof sockets are required and these must either be made upon fixtures or hung as shown in Fig. 77. Here stranded No. 14 rubber-covered wires are shown passing from the socket to the circuit wires to which they are soldered. The socket and lamp must not hang direct on the soldered joints but some other support must be supplied as by holding the socket wires under one of the porcelain cleats. The ordinary brass shell socket is a fairly standard device as now furnished by the best makers, but it is of

necessity small, and not very strong. It is decidedly better never to use such a socket except for an incandescent lamp and where an outlet is desired from which to take current for portable heaters, fans, and the like, to provide special wall or floor receptacles. This insures adequate current-carrying capacity and avoids mechanical injury to the comparatively frail sockets.

Flexible Cords. There are two chief classes of flexible cords, the plain twisted pairs and the various types of reinforced cord for portable use and where extra protection and strength is needed. It will be observed that the use of *any* type of flexible cord constitutes an exception to the general rule that conductors must be well separated. From one point of view it seems inconsistent to require wires to be well separated in walls, floors, and partitions and then permit the two conductors of a cord to be twisted closely together, with only a thin rubber insulation and a cotton braid on each. It is, in fact, a concession made to the necessities of the case and it cannot be denied that flexible cords may be and often are the weakest part of an ordinary wiring installation. It thus becomes at once evident why very definite limitations must be made in the use of cords. Fig. 78 shows types of flexible cords.

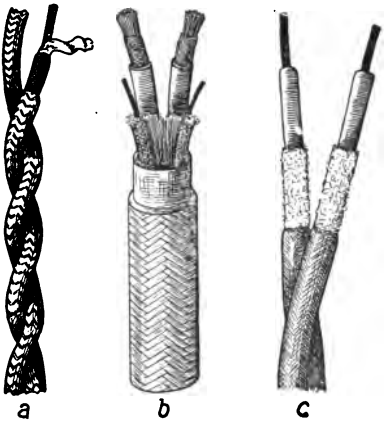


Fig. 78. Types of Flexible Cords

The common "twisted pair" cord consists of stranded copper conductors having a total carrying capacity equal to that of No. 18, 16 or 14 B. & S. gauge solid wire. No conductors smaller than No. 18 are allowed even for very small currents in order that the mechanical strength may not be too little. (It should be noticed also that No. 18 and No. 16 wires are permitted only for flexible cord and for fixture wiring, No. 14 or larger being required everywhere else.)

The copper strands are twisted or cabled together and wound with a wrapping of cotton thread both to keep the rubber from direct contact with the copper which it tends to corrode and to prevent a broken strand of wire puncturing the insulation.

The rubber insulation should be $\frac{1}{32}$-inch thick on No. 18 and No. 16, and $\frac{1}{64}$-inch on No. 14 cords and over each should be a fairly close braid of cotton thread. It is apparent that the finished cord so made with its two conductors twisted closely together does not afford any very great protection against a short-circuit resulting from broken or worn insulations and braid, and that the rubber and cotton braids supply a very fairly good fuel for any flame which is started.

The foregoing is not intended to lead to the conclusion that flexible cords should not be used, but rather to point to the reason why their use should be restricted and why they are open to objections not applying to ordinary separate and fixed wires.

Flexible cord should never be used as a substitute for regular fixed wiring. If the wiring provided does not give outlets at the proper places it should be changed in a proper and reliable manner. The common practice of festooning flexible cord along walls and ceilings and even through doorways and walls is to be strongly condemned as an unsafe and wholly inexcusable misuse of material. The use of flexible cord is limited to 300 volts. It should not be used to support lamp clusters as they are not capable of being secured well enough under binding screws to hold any considerable weight. The ordinary cord should be used only to hold lamps which under all usual conditions hang freely in air and which are not likely to be moved sufficiently to come into contact with surrounding objects. In brief, this cord is for "pendant" use only as its common name implies. The use of pendant cord for reinforced cord is a very common fault. Ragged half-broken lamp cord lying about on floors and looped over all kinds of supports constitutes a very common defect in installations, otherwise perhaps in fair condition. "Flexible cord fires" are as common as might be expected from the frequent misuse of this form of wire.

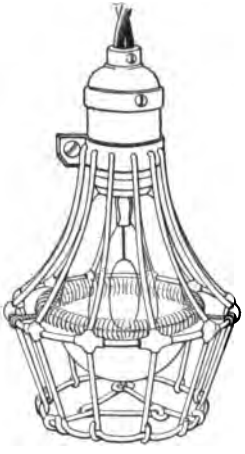


Fig. 79. Wire Guard for Portable Lamp

For all portable work including those pendants which are liable to be moved about, some form of reinforced cord should always be employed. In these the ordinary pendant cord is covered either with an outer rubber jacket and a stout "over-all" braid or where

the exposure to injury is less (as in offices and residences) with an outer woven braid only. These reinforced cords are far from indestructible and should be frequently inspected and renewed before an accident makes it absolutely necessary. The use of all kinds of flexible cord in show windows is expressly forbidden by the Code, because it has been found that it is subject to exceptionally hard

Fig. 80. Results of Careless Handling of Portable Lamps

usage there, and more especially because of the practical certainty that it will be used as a support for window decorations or goods of inflammable nature which have often been found *pinned* to it or supported by wires strung across it. A special kind of cord having a metal armor is, however, allowed in show windows.

In connecting flexible cords to sockets, rosettes or other devices, special attention should be paid to seeing that all the small copper strands are well tucked in under the heads of binding screws and that stray ends are not left sticking out to cause short-circuits. At all places where cords pass out of sockets or other fittings, smooth, well-rounded insulating bushings should be provided and a knot should be tied in the cord inside the socket cap or rosette, so that this knot will take the strain from the binding screws. Several special little fittings for this purpose are also on the market as substitutes for the knot. Pendant lamps wherever exposed to injury or at all liable to be brought into contact with inflammable material, and *all* portable lamps should be provided with substantial wire

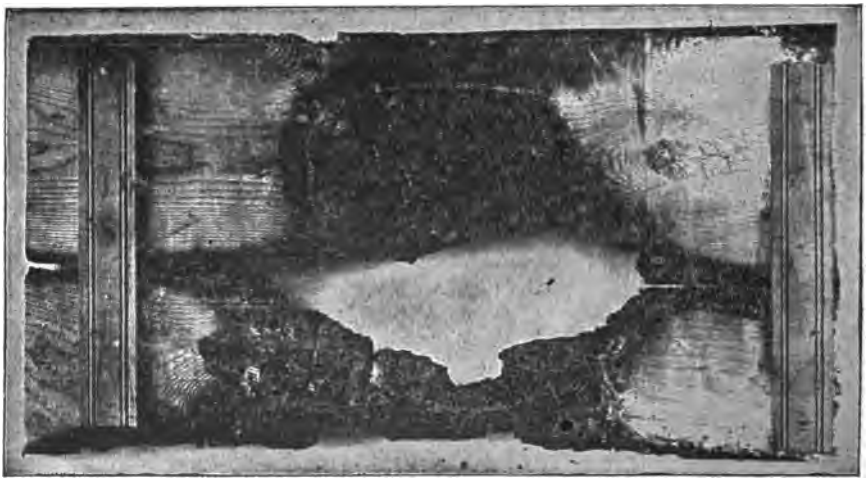


Fig. 81. Hole Burned by Incandescent Lamp Bulb

guards such as are shown in Fig. 79. Figs. 80 and 81 show the results of carelessness with hanging or portable incandescent lamps.

Arc Lamps on Constant-Potential Circuits. Each lamp, or each series of lamps, should be separately fused and the branch conductors should have a carrying capacity about 50 per cent in excess of the current required to provide for the heavy current required by the lamp in starting or when the lamp carbons accidentally become stuck. If this were not done it would be necessary, generally, to over-fuse the wires, which is objectionable.

Arc lamps are of many patterns but all of them contain resist-

ances or regulators which become very hot and, therefore, all the parts of the lamp and its case must be of non-combustible material and must be treated as sources of heat, that is, they must be installed well away from all inflammable stuff. The globes and netting about the carbons must be used in all cases. In general the resistances and all

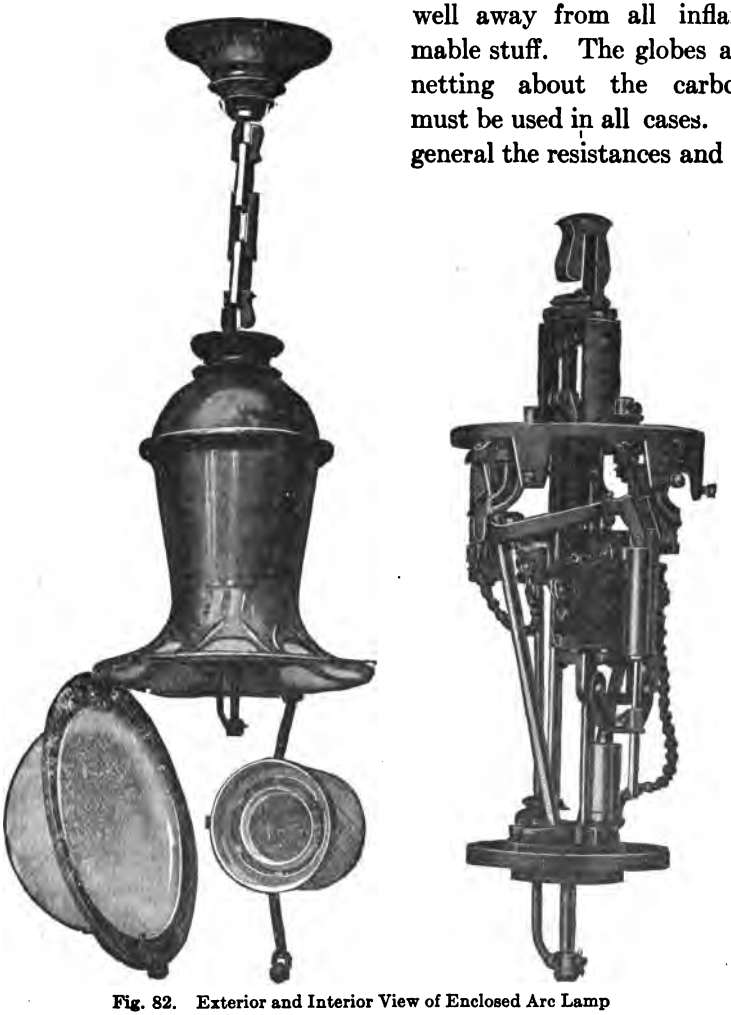


Fig. 82. Exterior and Interior View of Enclosed Arc Lamp

other accessories of the lamp except the controlling switch should be contained in the lamp case itself. Fig. 82 shows a modern type of enclosed arc lamp and its mechanism.

The "flaming arc" lamps now in common use call for the same precautions as the older patterns. In dusty or linty places special

precautions must be taken to prevent the accumulation of lint, etc., either on hot resistances, inside the lamp or on the switch usually furnished on the lamp. In general the same rules apply to mercury arc lamps as to the carbon arc lamps, except that the former do not present the hazards due to the hot carbon points.

TRANSFORMERS IN BUILDINGS

Except in central stations and substations, an outside location for transformers is always preferable and the underwriters do not allow any oil-cooled transformers in buildings except by special permission. This is because of the danger from the oil which may be boiled over or set on fire in case the transformer becomes overheated.

Fig. 83. Common Type of Oil-Cooled Transformer

Air-cooled transformers having the highest voltage of both primary and secondary under 550 volts may be installed inside buildings if the case is kept at least one foot from combustible material or separated from such material by being mounted on a suitable slab of slate or marble. Transformers sometimes become very hot in case of a partial or complete burn-out of the coils or from overloading and, therefore, should never be mounted directly against wood posts, beams, or walls. Fig. 83 shows a common type of oil-cooled transformer.

RESIDENCE OF ERNEST RECKITT AT EVANSTON, ILLINOIS
Ernest Mayo, Architect, Chicago

UNDERWRITERS' REQUIREMENTS

PART II

INSTALLATION OF WIRES IN BUILDINGS

The proper choice of wires and their safe installation constitutes the most important part of all electric equipment from the viewpoint of the fire hazard. It has already been stated that in all electric work, conductors, however well insulated, should always be treated as bare, and from one point of view, it may be said that the value of conductors as regards safety lies in their insulation rather than in the copper, for if we assume that a wire of adequate carrying capacity is chosen for a given purpose, there remains only the choice of a suitable covering or insulation on the wire and a reliable and workmanlike method of placing it.

No one material has yet been produced which has every desirable property as a covering and insulation of electric wires and cables. Among the desirable properties of a wire covering are elasticity, flexibility, waterproofness, good insulating quality and resistance to voltage strains, resistance to effects of changing temperature, acids, vapors, etc., and permanence. All of these properties are possessed by rubber in greater or less degree and, all told, to a greater degree than any other material. The properties of rubber-covered wires will be treated at greater length in another place, the foregoing statement being made here to emphasize the reason why rubber-covered wires are used almost exclusively in all inside wiring.

"Slow burning" wire is a copper conductor covered with three closely woven cotton braids saturated with a fire-resisting compound. Its use is limited to places where rubber is liable to be rapidly injured by high temperatures. Its insulating value is slight and it is not capable of resisting moisture.

"Weatherproof" wire consists of a copper conductor covered with three braids saturated with a moisture-proof compound. Its insulating value when new is low (much less than rubber) and it is very inflammable. Its use is practically confined to outdoors.

In the following sections it may be assumed that all references to wire mean "rubber-covered" wire.

Classification and General Principles. There are two classes of wiring which may be named for convenience: *enclosed* wiring and *non-enclosed* wiring.

Wires run on insulators such as cleats and knobs exposed on walls and ceilings or on knobs and through tubes concealed in floors and walls are the chief types of non-enclosed wiring. It will be observed that the distinction consists in the presence or absence of special wire-ways or channels for the wires. Wires must not be laid in plaster, cement, or similar finish, because such materials may contain either alkalies or acids which will injure the insulation and corrode the copper. Wires must never under any circumstances be fastened with staples because of the probable injury to the wire coverings, the insecure fastening obtained, and the possibility of such staples affording a path between wires in case twin conductors are used.

Twin wires must never be used except in conduit or where flexible conductors are necessary. The nearness of the two wires, on the opposite sides of the circuit, renders twin wire of any description somewhat more liable to failure and an injury to one wire generally involves an injury to both with resultant certainty of a short-circuit. The added safety of keeping the wires of a circuit separated is lost in twin wires.

In any scheme of wiring it is essential that all electric wires be installed so that they cannot come into contact at any point with any materials other than those expressly intended for their enclosure or support. This means that they should be kept absolutely free from contact with gas, water, or other piping, and from all metal work of any description unless it be that of piping, boxing, or molding provided as wire enclosures. Wires should also be installed so as not to touch woodwork or other combustible material, even if such material is not a good conductor. This general principle finds an exception in the case of wood molding.

Contact of wires with metallic substances may, in case of a failure of the insulation, permit dangerous arcs, short-circuits, or grounds, while contact with wood or combustible material is objectionable on account of setting fire to it in case of overheated wires or from leakage due to the presence of moisture on materials which when dry would be good insulators. These are, therefore, the general principles of wiring under the established rules and will be illustrated in the discussion of the various classes of wiring which follow.

Open Work in Dry Places. Wires in open work may be either rubber-covered, slow-burning, or—special and now little used wire having a weatherproof braid covered by a slow-burning braid—but as a matter of fact only rubber-covered wire is used to any extent

Fig. 84. Large Feeder Wires Exposed on Insulators

and it is much to be preferred except in exceptionally hot places as over steam boilers, where rubber insulation will deteriorate very rapidly. The rubber-covered wire used for open work has a single braid over the rubber. The chief advantages of open work are its cheapness and its accessibility. The latter may be of great advantage in cases where frequent changes and additions are likely to be required or where renewals of wire are frequent because of peculiarly unfavorable conditions such as exist in packing houses.

Open work finds its chief use in mills and factories and for large conductors which it is especially difficult and expensive to enclose in conduit. Fig. 84 shows an example of a set of large feeders run exposed on insulators. It should be noted that such a large group of heavy cables covered with the inflammable braid and rubber insulation furnishes a very considerable amount of fuel for fire and the necessity for excellent spacing and reliable fastening is obvious. The heavy porcelain blocks carried in metal frames as shown in the illustration are of an approved type. In all open work, wires or cables must be rigidly supported on non-combustible, non-absorptive insulators. Formerly wood cleats were used but these are now obsolete and have been replaced by porcelain. Where the voltage is less than 300 volts, wires must be separated from each other at least 2½ inches and from the surface wired over at least ½ inch in dry places—in damp places at least 1 inch. For voltages from 301 to 550 volts, the limit for "low-potential systems," the wires must be kept 4 inches apart and 1 inch from the surface wired over.

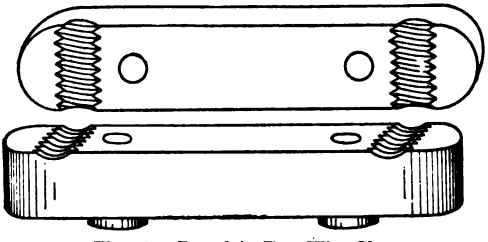


Fig. 85. Porcelain Two-Wire Cleat

Split knobs or cleats must always be used for the support of conductors which are smaller than No. 8 B. & S. gauge except when they are found at the end of runs. Fig. 85 shows a typical form of a two-wire cleat and Figs. 86 and 87 show good

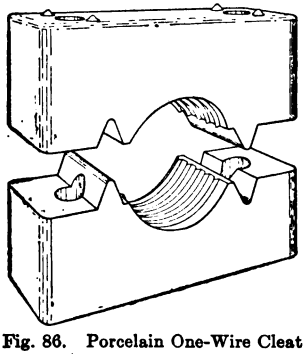


Fig. 86. Porcelain One-Wire Cleat

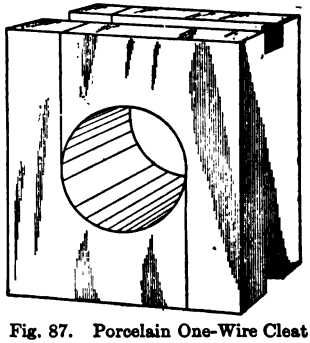


Fig. 87. Porcelain One-Wire Cleat

forms of one-wire cleats for heavier conductors. No. 6 wire is about the largest which should be installed in cleats like those in Fig. 85, and for cables larger than No. 0000 B. & S. gauge, some form of iron rack for the insulators is desirable in order to secure the needed mechanical strength and rigidity.

The rigid supporting necessary for open wiring requires under ordinary conditions along flat surfaces, supports at least every 4½ feet. This distance should be decreased wherever wires are liable to be disturbed especially if the wires are small. The following comment is from the Rules of the Associated Factory Mutual Fire Insurance Companies:

The proper distance between insulators depends largely on the surroundings. In places where ceilings are low, or where belts, shafting, or other

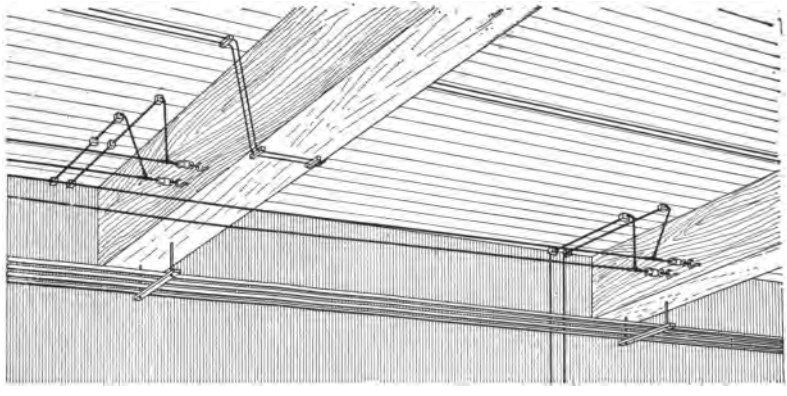


Fig. 88. Wiring on Ceiling Showing Use of Strain Insulators

machinery may require frequent attention, insulators should be placed every few feet, in order to prevent the wires from being displaced by careless or unavoidable blows from workmen. On the other hand, with a high ceiling and no chance of derangement, a greater distance would be allowable.

The whole idea is to so rigidly secure the wires that they cannot come in contact with each other or any other conductors, if loosened by shrinkage of timbers and floors or by careless knocking.

Special methods must be followed at corners and in wiring over broken surfaces as on ceilings of mill-constructed buildings. Fig. 88 shows a use of "strain insulators" in making a turn on a ceiling. These are insulating balls having rings set in each side, the wire being looped through one ring and the hook on the beam through the other. Turnbuckles may be used to keep the wires taut. Ordi-

nary cleats will not hold heavy wires at corners. With conductors of No. 8 B. & S. gauge or over, it is not necessary to "break around" beams but smaller wires should be carried around the beams as shown in Fig. 89. The cleats on the ceiling should be set off from the timbers 3 or 4 inches. If they are closer, the shrinkage of the timber or rough usage is liable to bring the wires into contact with the timber. On the other hand if the distance is greater, the wires are too much exposed to injury from brooms, ladders, and the like. With this arrangement any slack wire can be taken up by moving the cleats a little nearer the corner. Where beams are widely spaced some such method of support as that shown in Fig. 90 should be followed. Fig. 91 shows a less desirable method of support. In low ceiling rooms where wires are exposed to mechanical injury, wood guard strips (see Fig. 92) may be used to advantage. Where wires pass through partitions or walls they must be protected by tubes of porcelain or iron pipes lined with flexible tubing.

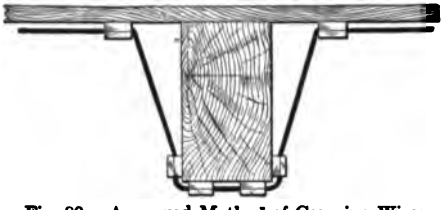


Fig. 89. Approved Method of Carrying Wires Around Beams

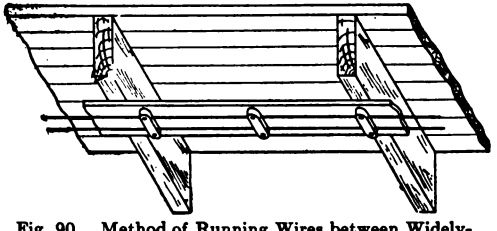


Fig. 90. Method of Running Wires between Widely-Spaced Girders

Wires on side walls must be protected from injury to a height of at least 5 feet from the floor either by wood boxing or by iron pipe as

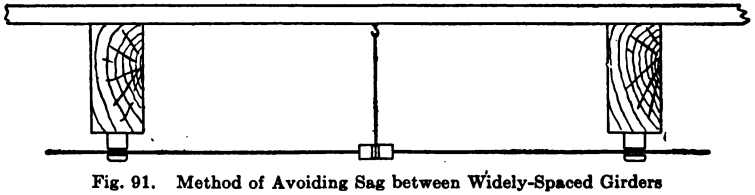


Fig. 91. Method of Avoiding Sag between Widely-Spaced Girders

shown in Figs. 93 and 94. When iron pipe or conduit is used the insulation of each wire must be reinforced by flexible tubing extend-

ing from the insulator next below the pipe to the one next above it (see Fig. 93). For alternating current both wires of the circuit must be in the same pipe.

Open Wiring in Damp Places. The installation of electric wires in places exposed to dampness presents some peculiar difficulties requiring special methods. A film of water such as may be formed by steam or otherwise by condensation is a very fair conductor of electricity, and may reduce or even entirely destroy insulation which would be quite adequate in dry places. Acid or alkaline fumes or vapors are also good conductors in some cases and in addition they are liable to injure both the insulators and the copper of electric wires.

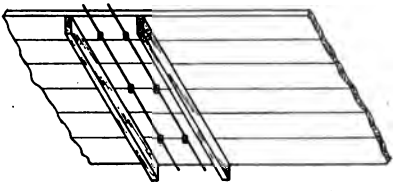


Fig. 92. Diagram Showing Use of Guard Strips

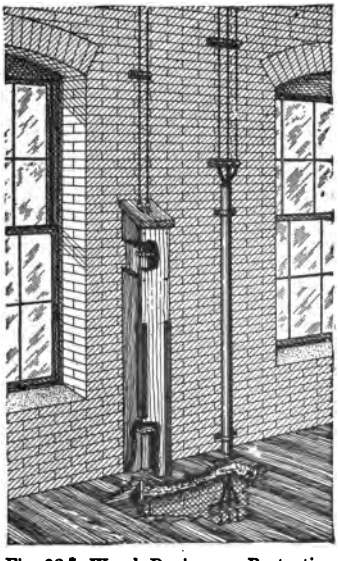


Fig. 93.* Wood Boxing as Protection for Wires on Side Walls

Fig. 94.* Protecting Wires on Walls by Iron Piping

In paper mills, breweries, soap factories, packing houses, dye works, and cold storage rooms special pains must be taken to insure

*Courtesy Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.

permanence and reliability of all electric fittings and appliances.

The Code does not prescribe at length precautions to be taken in damp or otherwise exceptionally troublesome places, but merely specifies for open wiring that only rubber-covered wire be used and that the separation between wires shall be at least 2½ inches for voltages up to 300 volts (4 inches for higher voltages) and that all wires be kept *1 inch* from surface wired over instead of only ½ inch as in dry places.

There are two objections to the use of steel conduits in damp places, *first*, that all metal work is especially liable to corrosion even when well enameled or galvanized; and *second* and *more important*,

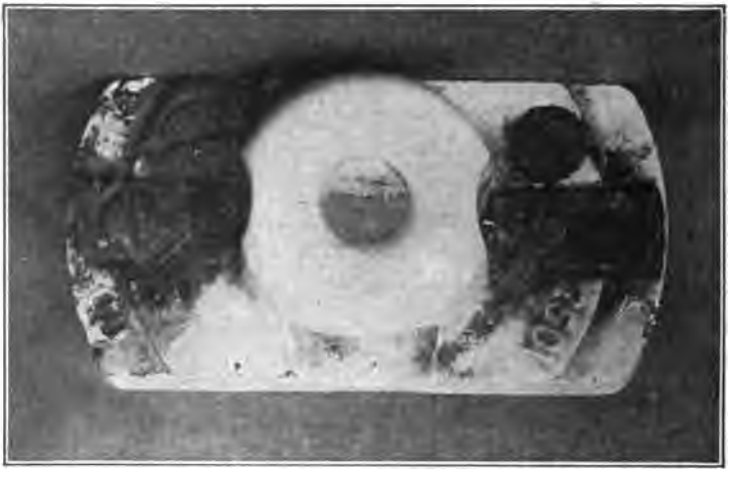


Fig. 95. Corroded Rosette Improperly Mounted on Damp Ceiling

that water is apt to collect in the pipes and gradually deteriorate the insulation. This water results from moisture condensed from the air during changes in the temperature and amount of water vapor present in the atmosphere. This condensation is often sufficient to be very troublesome and often leads to the adoption of open wiring of special forms rather than a complete conduit installation. Usually conduit is used in the more exposed or crowded places only and in such parts of the plant as are less liable to dampness.

In many breweries, packing houses, and other plants, walls and ceilings are continually dripping with water and in some factories fumes and vapors are present in large quantities at all times. A

fairly good solution of the problem is possible where only water is to be guarded against, but where corrosive vapors exist, no thoroughly satisfactory method has been devised to resist indefinitely the corrosive actions. A good asphaltum paint will protect cabinets and conduits for a time and frequent repainting will extend the life of these parts of the equipment for a considerable period. It is evident that current-carrying metal parts should be enclosed in tight boxes wherever feasible and very frequent and thorough reinspections of the entire equipment should be made followed by renewals as faults develop. Fig. 95 shows the corrosion on a rosette improperly mounted.

In rooms where dampness is excessive the wires are sometimes run open in inverted wood troughs, one form of which is shown in Fig. 96 and in detail in Fig. 97. This trough serves to separate the wireway entirely from a wet ceiling and the sloping surfaces serve to carry the moisture away from the knobs on which the wires are held. The V-shaped blocks are spaced about $4\frac{1}{2}$ feet apart and care is taken to make a close joint where the running boards come together at the top. The whole is thoroughly painted with an insulating paint. Fig. 98 shows open wiring on flat running boards for moderately damp places like basements or cellars.

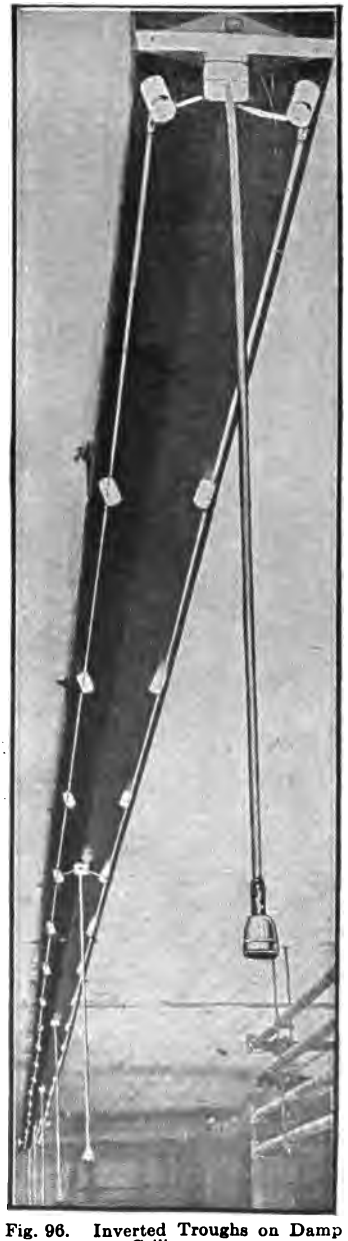


Fig. 96. Inverted Troughs on Damp Ceilings

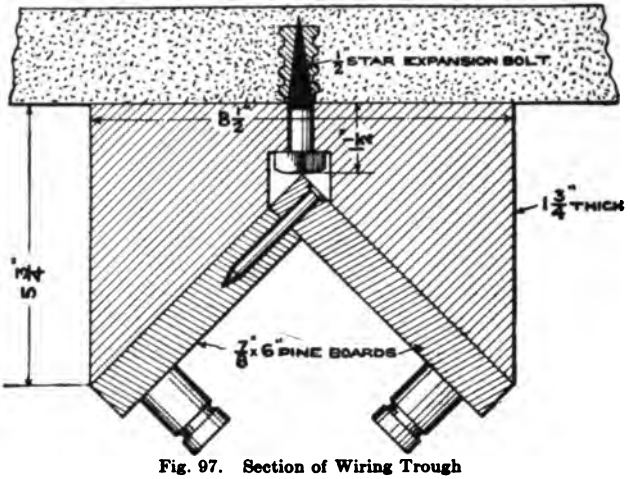


Fig. 97. Section of Wiring Trough

Fig. 98. Example of Wiring on Running Boards in Damp Place

All drop cords should be of extra heavy reinforced type or of standard rubber-covered wire and only weatherproof keyless sockets should be used with all wire joints soldered, taped and painted in the best manner. Motors and their resistance boxes or starters should be kept out of damp rooms if possible but if in such rooms, they should be installed with special reference to accessibility, cleanliness, and separation from wet floors or walls. Posts in middle spaces of rooms will generally afford better locations than side walls, which are always wet. Wood cabinets lined with slate or with stiff asbestos board are preferable in many wet places to metal enclosures if they are kept well painted inside and out with an asphalt or insulating paint. A single incandescent lamp in such a cabinet if kept constantly burning will tend to keep the interior of the box dry, if the box is tight and if the door is kept closed. With a glass panel in the door the lamp may be seen at all times.

Wires in Molding. *Wood Molding.* Wood molding is one of the commonest forms of protection for wiring and when properly used affords a cheap and fairly satisfactory installation. From one point of view it seems inconsistent to take every precaution in other forms of wiring to keep wires away from direct contact with wood surfaces, such as ceilings and walls and hidden spaces in frame partitions and floors, and on the other hand to permit them to be run in small grooves in strips of wood, as in molding work. The solution to this somewhat theoretical objection is found in the fact that in molding, the wires are completely enclosed in a wire-way especially designed for them, rather than allowing them to hang or be drawn over wood objects in a more or less accidental manner with no real protection, and a still better solution is to be found in the unquestionable fact that the use of molding under proper conditions has proved generally satisfactory. The use of wood molding is, however, prohibited in many large cities by local ordinances.

Wood molding should *never* be used in concealed spaces or in damp places or for voltages over 300. The rule as to damp places precludes its use in cellars and basements, anywhere out-of-doors and generally on outside brick walls which are often more or less damp and likely to "sweat" and thus introduce moisture back of the molding. If the wood molding becomes soaked with water there is a liability of leakage of current from one conductor to the other or

to "ground." If conductors in molding become overheated by excess current the wood may become charred, and charred wood is a fair conductor. The possibility of fire from such a cause is evident.

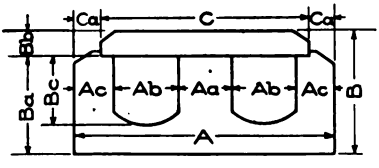


Fig. 99. Section of Two-Wire Molding

Molding should be made of hard wood and should be thoroughly impregnated inside and out with a paint- or moisture-repellant. It must be made in two pieces, a backing containing the wire grooves, and a capping. The tongue between wires must be at least $\frac{1}{2}$ inch thick and the wood under the grooves must be at least $\frac{3}{8}$ inch thick. Figs. 99 and 100 give the forms of two- and three-wire moldings. Larger moldings are sometimes used for heavier wires but generally only small conductors are placed in wood moldings. Only good rubber-covered wire should be used and no joints or splices made in the wires in the molding, but where branch taps are necessary some form of fitting approved for the purpose should be employed. Such fittings as the one shown in Fig. 101 provide porcelain bases with suitable binding screws for the main and the branch wires and a cover over the joints.

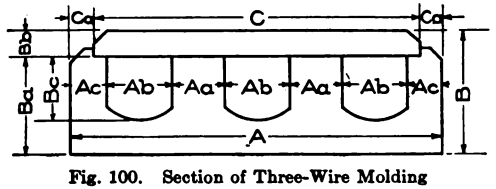


Fig. 100. Section of Three-Wire Molding

Fig. 101. Device for Making Tap in Molding

A large variety of receptacles (both for lamps and plug connectors), rosettes, etc., are available for use with wood molding and should be used instead of the ordinary patterns. Where it is desired to insert a snap switch, either a special switch approved for mounting directly on the molding, or else a sub-base of porcelain or hard wood on which the switch can be securely fastened should be employed.

Wood molding is often used in connection with other types of wiring and in such cases special attention should be given to making a good mechanical job where the conductors enter or leave the molding. Fig. 102 shows one form of protector for use in protecting wood molding at floor levels. The capping should be carefully and tightly nailed in place and under no circumstances should fixtures be attached to molding or any hooks or nails be driven into it for the support of lamp cords or other objects. The use of wood molding in show windows is undesirable: *first*, because of the dampness apt to exist there; and *second*, because in the process of decorating windows and arranging displays of merchandise nails will surely be driven into the molding with resultant injury to the insulation of the wires.

In conclusion, it may be said that wood-molding work is cheap and may be used properly, but is inferior to most types of wiring.

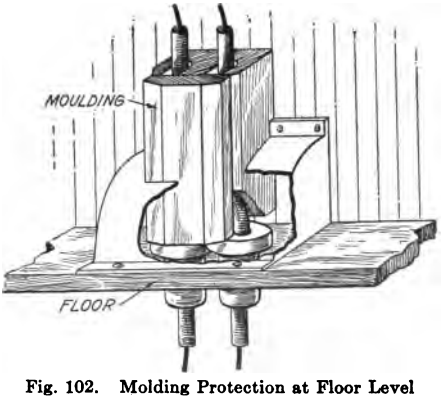


Fig. 102. Molding Protection at Floor Level

Metal Molding. Recently several types of *metal molding* have been introduced which are free from some of the objections adhering to wood molding, and make possible a neat, inexpensive, and convenient installation. In these moldings, as in those of wood, the wire is *laid in*, not drawn in as in conduits, and is covered by a metal capping. At present the underwriters' rules limit its use to circuits requiring not more than 1320 watts of energy.

Special fittings are provided for angles, bends, taps, and crosses, and for switch, rosette, and receptacle bases. The molding can be bent for slight curves or offsets and when carefully installed gives good results. Fig. 103 shows such a molding and fittings.

Metal molding must be continuous from outlet to outlet and where it passes through floors it must be enclosed in an iron pipe for added protection. The backing must be secured by screws or bolts with heads countersunk so as not to obstruct the wire-way. Between

lengths of molding and at all fittings and outlet boxes the joints must be mechanically and electrically secured. The fundamental idea is to secure an absolutely continuous metallic conductor throughout the entire run of molding and in addition the molding must be well grounded in a permanent manner. In this respect the molding is regarded in the same light as rigid metallic conduit. The reasons

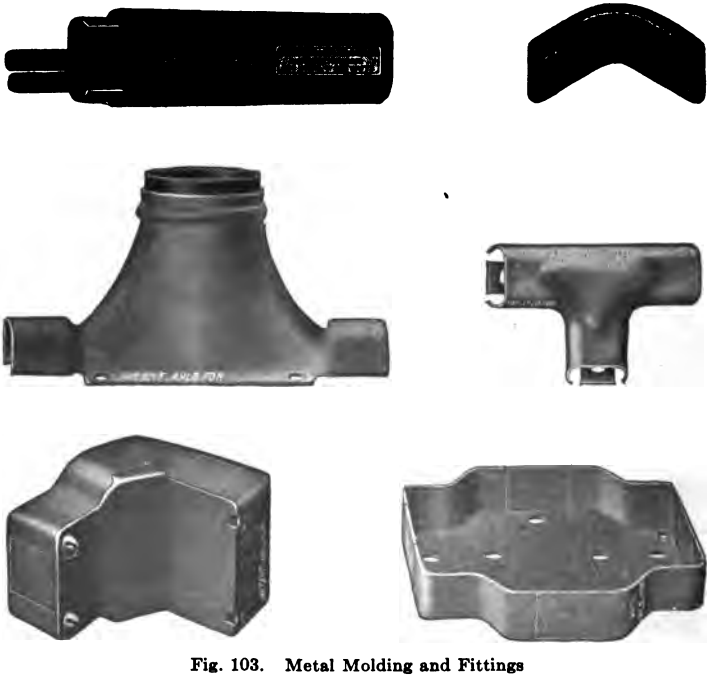


Fig. 103. Metal Molding and Fittings

for requiring good electrical continuity and grounding will be explained later when the subject of conduit is considered.

Concealed Work. This kind of wiring is also often called "knob and tube" work since the wires are held on knobs and passed through tubes of porcelain. The great advantage of this method of wiring consists in the cheapness and ease with which a building, especially a frame building, can be wired. The greatest objection to the knob and tube work lies in the fact that the wires are wholly unprotected from mechanical injury and the building is not protected from the results of arcing between wires in case of a cross or short-circuit.

It is no doubt true that knob and tube wiring is the least reliable form of electric work and inferior to good conduit or armored cable. Where wires can be run open and are not exposed too much to mechanical injury, they are probably somewhat safer than when concealed on porcelain supports in walls, floors, and partitions. Open wiring is not possible in residences or where good appearance is a requisite, and the somewhat greater cost sometimes prevents the use of conduit. Therefore, recourse is made to concealed wiring and where an installation is carefully made a reasonably good result may be obtained. In many cities concealed work is entirely forbidden within "fire limits", that is, in the closely-built sections, but it is still very extensively employed in places where first cost and quickness of installation are the prime factors. Only good rubber-covered wire is allowable in concealed work.

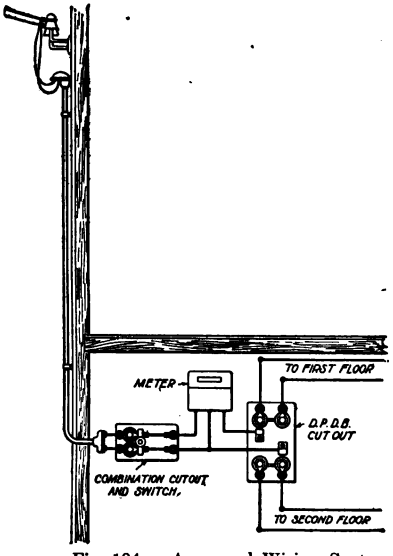


Fig. 104. Approved Wiring System on Entering Building

Approved Installation in a Residence. The wiring of a residence may be taken as an illustration of how the work should be done. The service wires are brought in through the wall near the ground preferably in iron conduit but allowably through bushings with drip loops outside, Fig. 104. As near as practicable to the point of entrance is placed the main service fuse and switch. These should be in a suitable cabinet though this is not obligatory. It should be understood that the wiring is placed during the erection of the building. In an ordinary frame building the wiring will be done just after the rough flooring and the partition studding has been placed, but before the lathing or any plastering is done. It should all be completed except the final connection of service wires, fixtures and fittings before any of it is enclosed or hidden, so that inspection may be made while all parts are accessible and visible.

From the service cabinet and meter as many circuits are run as may be required to feed the lamps and other devices to be connected,

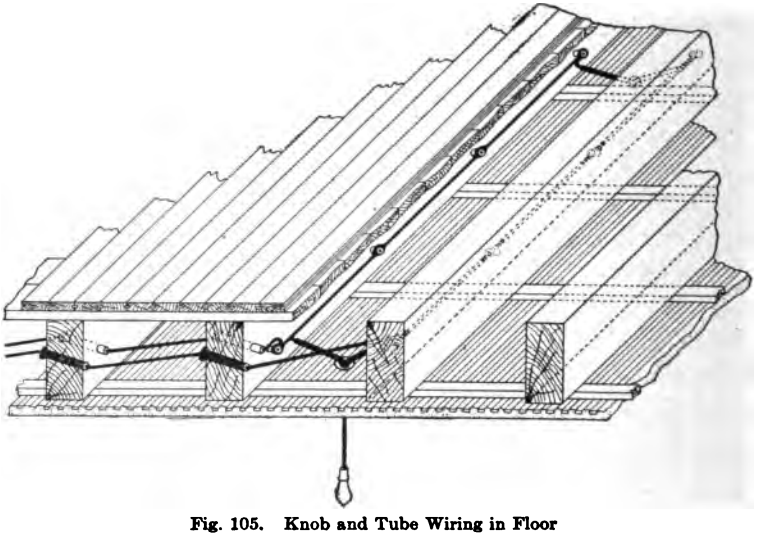


Fig. 105. Knob and Tube Wiring in Floor

each being fused at the service center unless there is no change at that point in the size of wires. These circuits will pass up through the floor within porcelain tubes and will thence be carried on porcelain knobs fastened to the timbers and studding not more than 4½ feet apart. Where the wires pass through floor timbers, porcelain tubes, straight and smooth, must be used in holes bored in the wood and just large enough for the tubes. In general we may say that knobs are used where the wires run parallel with floor beams, and tubes where the wires are run at right angles to the beams. Fig. 105 shows the general method and Fig. 106 illustrates a two-piece knob. These are required for wires less than No. 8 B. & S. gauge and are preferable to one-piece knobs which need a tie-wire. The wires should be run singly on separate timbers and must, except as noted below, be kept

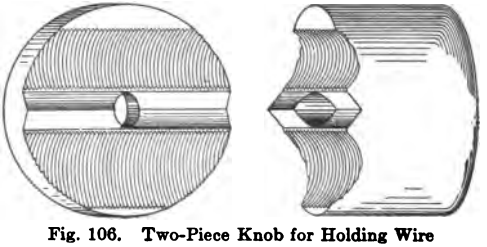


Fig. 106. Two-Piece Knob for Holding Wire

everywhere 5 inches apart. Fig. 107 shows clearly the use of the knobs and tubes, but the tubing shown on two of the upper wires

Fig. 107. Knob and Tube Wiring Showing Objectionable Features

is objectionable and knobs should have been used instead. It is very desirable to use metal outlet boxes at *all* outlets and the added expense of so doing is not large. Where flush switches or receptacles

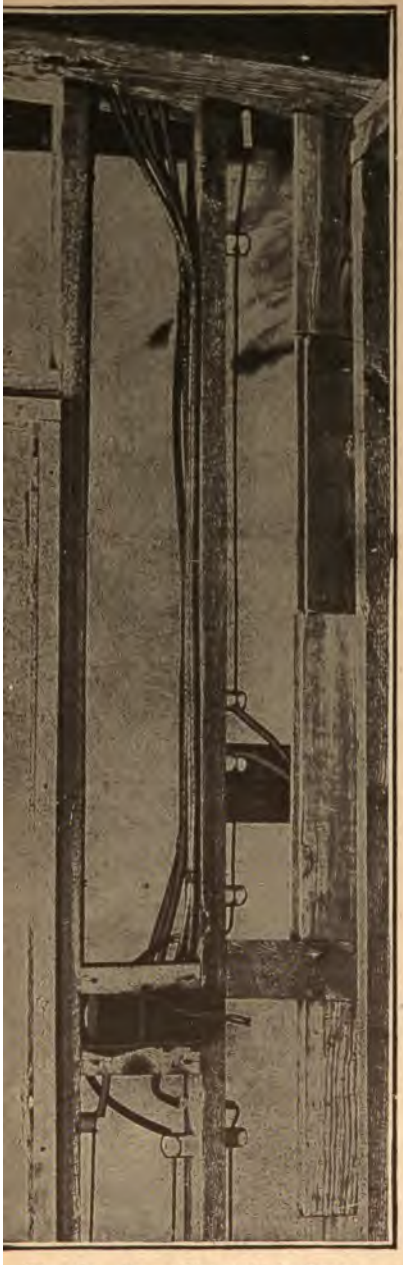


Fig. 108. Proper Use of Outlet Boxes

Fig. 109. Wiring in Partitions Showing Use of Porcelain Tubes

are used, metal boxes are absolutely necessary and in Fig. 108 several such boxes are shown as well as the method of mounting them on cross strips between the uprights. This illustration shows also an allowable use of flexible non-metallic tubing on wires in concealed work where it is impracticable to maintain the 5-inch separation.

Fig. 109 shows at the bottom the extra porcelain tube which should be put on each wire passing through timber at the bottom of a plastered wall to protect it from the droppings of wet plaster which will fall on it during the process of closing in the wall surface. This picture also shows very clearly the flexible tubing which must separately enclose each wire at every outlet, reaching from the last porcelain support into a switch box, or on ceiling or wall outlets, where no box is used, at least 1 inch beyond the surface. In the case of combination gas and electric fixtures the tube must extend at least flush with the outer end of the gas pipe as in Fig. 110.

When in a concealed knob and tube system, it is impracticable to place the whole of a circuit on non-combustible support of glass

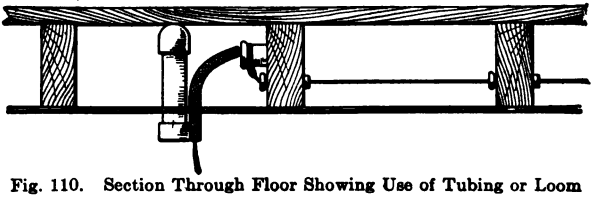


Fig. 110. Section Through Floor Showing Use of Tubing or Loom

or porcelain, that portion of the circuit which cannot be so supported must be installed with *approved* metal conduit, or *approved* armored cable, except that if the difference of potential between the wires is not over 300 volts, and if the wires are not exposed to moisture, they may be fished if separately encased in *approved* flexible tubing, extending in continuous lengths from porcelain support to porcelain support, from porcelain support to outlet, or from outlet to outlet.

There can, of course, be no assurance that such fished wires do not lie in close contact with gas or water pipes, or other wires, and so there is need of the protecting tubing.

In judging an installation of wires in concealed work, special attention should be paid to the wire joints. The rules allow these to be made in concealed spaces by means of soldered joints well covered with both rubber and friction tape. The wiring is usually

on the so-called "tap plan," that is, taps or branches taken off wherever convenient. The necessity for good workmanship is evident as bad joints may easily set fire in dry floor and wall spaces. Fig.

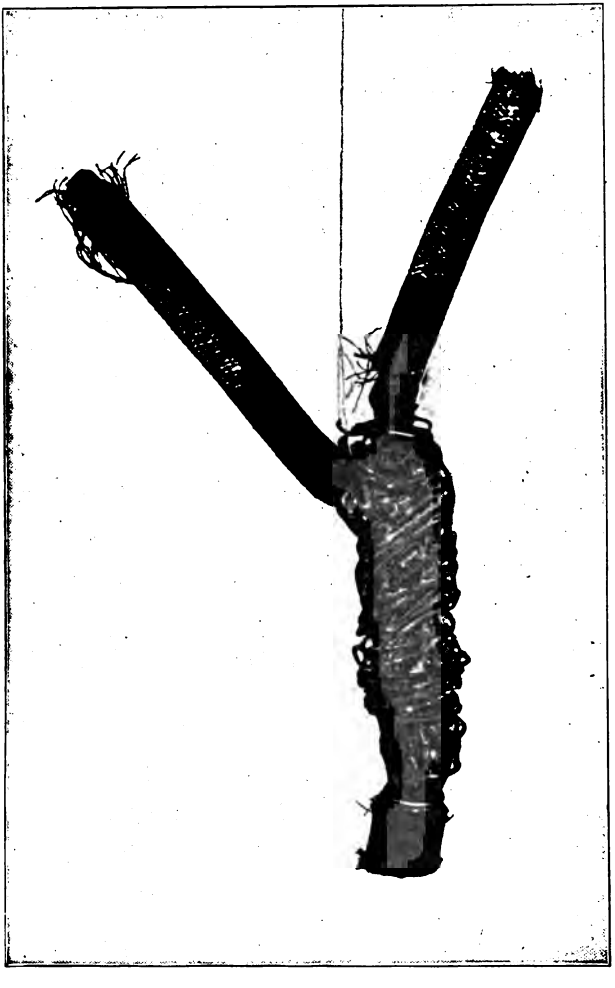


Fig. 111. Defective Joint Found in Actual Use

111 shows such a defective joint which was found behind a lath-and-plaster partition. The joint was not taped and was hot when discovered. What is called the "loop-plan" is occasionally employed, all joints or taps being made at outlets where suitable boxes are

provided. This involves the use of more wire, makes the conditions at outlets more crowded, and is perhaps not as good for concealed work under the conditions usually obtainable. Either system is permitted by the rules.

Armored Cable. Armored cable for interior wiring consists of double-braided, rubber-insulated, twin wires, covered with a spiral steel strip armor which protects the conductors from injury and is at the same time flexible. It is largely used in wiring old buildings since it can be drawn into concealed spaces without fear of injuring the conductors. It is also used for new work and is in some ways easier and cheaper than rigid conduit. Fig. 112 shows a piece of twin-conductor house cable and some of the fittings for use with it.

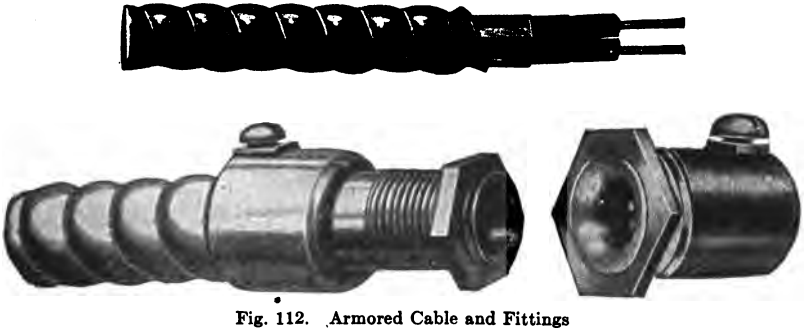


Fig. 112. Armored Cable and Fittings

With armored cable all joints must be made at outlets or in cabinets or junction boxes which are always accessible. No taps or joints are permissible except at such outlets or boxes. Great care should be taken to secure the armor very firmly to all outlet boxes in a way to give a good connection both electrically and mechanically, and the armor system must be permanently and reliably *grounded.* Where dampness may be expected there must be a lead sheath between the braided wires and the outer armor since the cable is not thoroughly moisture-proof.

Armored cable installations are superior to molding, open work, or concealed work, in that the wires are better protected. The fact that twin wire is used instead of separate conductors is at least a theoretical disadvantage, and the cable unless leaded is not absolutely waterproof.

The chief disadvantages of armored cable as compared with rigid conduit, consist in the somewhat greater difficulty of making good connections to the armor at outlets and still more in the impossibility of drawing out wires which have proved defective. However, for many places a thoroughly good job can be done with armored cable. Fig. 113 shows a characteristic piece of work of this sort.

Conduit Work. The earlier forms of conduit for interior wiring were made of paper or fiber and later of paper with a thin brass casing but these forms are now obsolete and entirely displaced by steel conduits made of either rigid pipe or flexible steel spirals. A limited use is still made of a form of conduit having a steel pipe

Fig. 113. Wiring Showing Use of Armored Cable

lined with a heavy paper impregnated with some material to exclude moisture. This is, however, going out of use and almost all conduit work is now done with unlined pipe. Conduit, however, differs from ordinary commercial pipe such as is used for gas, water, or steam, in that it is carefully cleaned in the process of manufacture and then protected from rust both inside and outside by a good baked enamel or by some form of zinc coating. *Rigid conduit*, Fig. 114, gives a rather more workmanlike job than *flexible conduit*, Fig. 115, but the latter can be used in some places, especially in old buildings where

the use of rigid pipe would be impossible. If well fastened at all outlets and at all bends it affords a protection to wires second only to the rigid conduit. The complete protection afforded by conduit

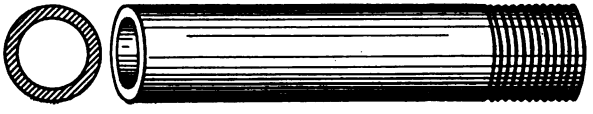


Fig. 114. Rigid Conduit

both of the wires from mechanical injury, and of the surrounding parts of the building from fire resulting from a burn-out of the wires, makes conduit work undoubtedly the safest form of electrical installation and one which is becoming more and more used, not only in the more expensive type of buildings but also in cheaper work as well.

The essential principle of conduit work is to furnish a complete, strong and unbroken metal enclosure for conductors between outlets and to give to this metal-pipe system an electrical continuity and carrying capacity sufficient to serve as a safe path for any current which the failure of conductors within may impose upon it, for a time long enough to operate the fuses or circuit breakers protecting such conductors. It is also an essential characteristic of a correct conduit installation that all conductors can be *drawn in* after the entire conduit system is put into position and can at any subsequent time be *drawn out* in case any wire fails and must be replaced. These fundamental ideas will explain the reasons for most of the details prescribed in underwriters' rules for conduit work.

The construction details of steel conduit will be briefly discussed later and we consider here only methods of installing it.

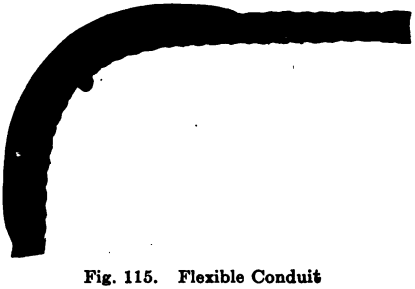


Fig. 115. Flexible Conduit

There must be no breaks in the conduit system, that is, the pipe must be continuous from outlet to outlet or junction boxes. At every outlet metal boxes must be provided which the conduits must properly enter and to which they must be mechanically secured. This is usually accomplished by means of either

threaded lock nuts on the pipe outside the box and threaded bushings on the pipe inside the box or by threading the conduit into tapped holes in the box. With flexible conduit a special approved clamp must be used for this purpose. Fig. 116 shows a box with a rigid conduit on one side and a flexible conduit on the other side together with a few of the fittings used in connection with it. No conduit having an internal diameter less than $\frac{5}{8}$ inch is allowable since this is as small as will permit wires of required minimum size to be drawn in without injury.

All elbows and bends in the piping must be so made that the conduit will not be injured and there should not be more than the equivalent of four quarter turns from outlet to outlet, not counting bends at the outlets themselves. If more turns are required, or wherever it would be difficult to draw in the wires, additional outlets called junction- or pull-boxes should be put in to facilitate the insertion of the wires. There should be no sharp edges, burrs or other obstructions either in conduits, at couplings between lengths, or at outlets, as they are apt to injure the wire coverings. Therefore, all ends of pipe should be reamed out before they are put into the pipe couplings or into boxes, and all bushings should have smoothly rounded edges.

Fig. 116. Outlet Box with Connecting Conduit

The entire conduit system must be installed complete and, in fact, all the mechanical work on the building must be completed as far as possible, before any conductors are drawn into the conduits.

Pains must be taken to make all joints tight, so that there will be no bad electrical connections between parts of the metal system. It is not, of course, expected that under normal conditions the conduits will carry any current, but under some circumstances if the insulation of a wire fails, current may pass over the conduit. If the

conduit is well grounded and all joints are well made a safe path to "ground" is afforded for a current large enough to blow the fuses protecting the circuit, thus cutting off the current before the pipe is overheated or burned through at the point where the bared wire has come into contact with it.

Conduits and gas pipes must be securely fastened in metal outlet boxes so as to secure good electrical connection. Where boxes used for centers of distribution do not afford good electrical connection, the conduits must be joined around them by suitable bond wires. Where sections of metal conduit are installed without being fastened to the metal structure of buildings or grounded metal piping, they must be bonded to a permanent and efficient ground connection.

It is rarely possible to perfectly insulate a conduit system throughout, and a positive ground is, therefore, required, so as to provide a definite path for leaking currents and thus prevent them from escaping through parts of a building, etc., where they might do harm.

The size of conduit which should be used for different sizes of wire or for different numbers of wires of specified size, depends upon the length of run between outlets where wires can be pulled or fed in, upon the number and the radius of bends and the thickness of the insulation on the wires. The rules, however, state that the same conduit must not contain more than four two-wire, or three three-wire circuits of the same system, except by special permission of the Inspection Department having jurisdiction, and must never contain circuits of different systems, that is, from different generators whether of the same voltage or not or whether both d. c. or a. c. or one of each.

In tall buildings special provision must be made to support the conductors in the vertical conduits to remove their weight from the connections, and the spacing of supports in such cases is prescribed as follows: No. 14 to 0 every 100 feet; No. 00 to 0000 every 80 feet; 0000 to 350,000 c. m. every 60 feet; 350,000 c. m. to 500,000 c. m. every 50 feet; 500,000 c. m. to 750,000 c. m. every 40 feet; 750,000 c. m. every 35 feet.

The following methods of supporting cables are recommended:

(1) A turn of 90 degrees in the conduit system will constitute a satisfactory support.

(2) Junction boxes may be inserted in the conduit system at the required intervals, in which insulating supports of *approved* type must be installed and secured in a satisfactory manner so as to withstand the weight of the conductors attached thereto, the boxes to be provided with proper covers.

(3) Cables may be supported in *approved* junction boxes on two or more insulating supports so placed that the conductors will be deflected at

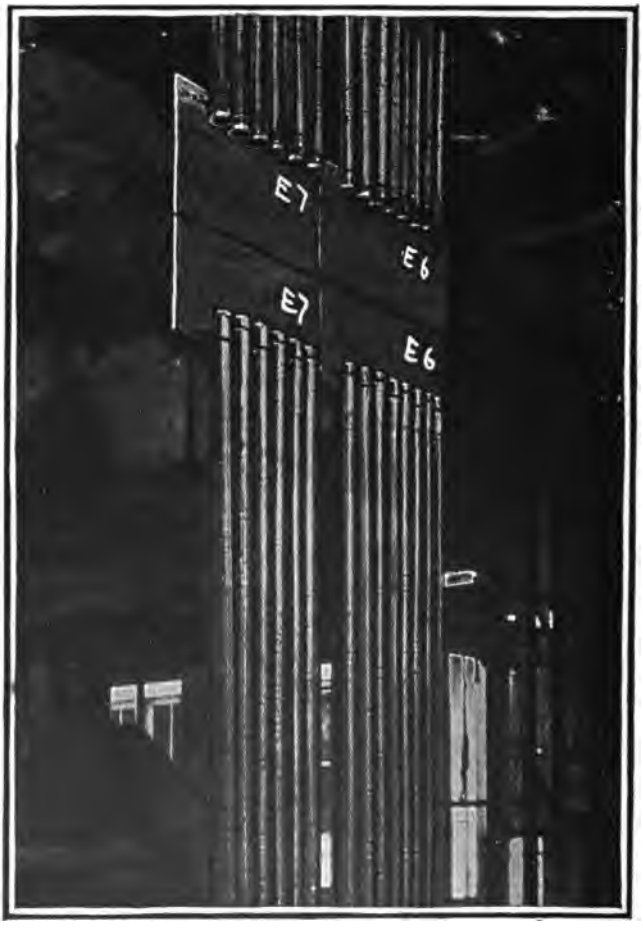


Fig. 117. Method of Supporting Conduit Risers

an angle of not less than 90 degrees, and carried a distance of not less than twice the diameter of the cable from its vertical position. Cables so suspended may be additionally secured to these insulators by tie wires.

The second method is illustrated in Fig. 117 where a space has been left in conduit risers. The conductors will be held to the back

plates by clamps and the whole will finally be enclosed in a heavy steel box which will form the connecting bond in the riser system. Fig. 118 shows one form of cable clamp used for this purpose.

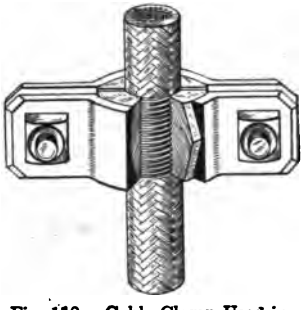


Fig. 118. Cable Clamp Used in Conduit System

Wires for conduit must be rubber-covered and have a double braid over the rubber. Twin wires are universally used for the smaller sizes, No. 14 to No. 10, and these have a braid over the rubber of each conductor and a second braid over both conductors together. For larger sizes single conductors, double braided, are used and for the largest sizes only one conductor is usually run in a pipe It should be noted, however, that for alternating-current systems the two or more wires of any one circuit must be drawn in the same pipe since otherwise there will be excessive heating of the metal pipes due to a magnetic action peculiar to alternating currents and known as "induction." Fig. 119 shows three large feeder ducts passing out of a steel service box. In this case the circuit was three-wire direct current.

The design of a conduit system of wiring for a large building may be a problem of some magnitude involving no little engineering skill and experience if the most economical, efficient, and sightly results are to be secured. A full exposition of the methods followed and the reasons for them does not fall within the scope of this book but the following general considerations are of some value in judging both the advantages of conduit work and the excellence of any given installation. In all conduit work it should be remembered that no taps or joints are permitted in conductors except at outlets, junction boxes, and cabinets, and that all these must be in accessible places. By accessible is meant accessible not only during the process of installation of the system but also after the building is completed and in use. A junction box is not "accessible" if it is necessary in order to get at it, to take up portions of floors or make openings in ceilings or side walls. This prime requisite of conduit work makes it necessary to run all conductors on the "loop" plan which means that all lines, branches, and control circuits (as to switches) will consist of a pair of wires starting at the same point at some outlet box

or cabinet and running generally in the same pipe to some other outlet where the socket, switch, or other device is placed. Conduit systems may be made with the piping concealed or exposed as may be dictated by the character of the building and the finish desired.

In frame buildings where the electric installation is put in during the original construction the conduits are placed after the main framing and partitions are in position and will be arranged to pass through walls and floors with the outlet boxes and cabinets set and fastened securely at or very near the places where they will be when

Fig. 119. Steel Service Box and Feeder Pipes

the building is done. In laying out such work little regard need be paid to having pipes run straight or parallel to each other so long as they are so shaped at bends and otherwise disposed as to make it easy to draw in the wires. The chief considerations are the position of outlets, the proper pipe sizes for the wires, and the proper subdivision to secure correct fusing of incandescent lamp circuits according to the rule which permits not over 660 watts on any such circuit.

Characteristic Conduit Installation. Fig. 120 shows a characteristic layout for conduits and outlets for a small apartment

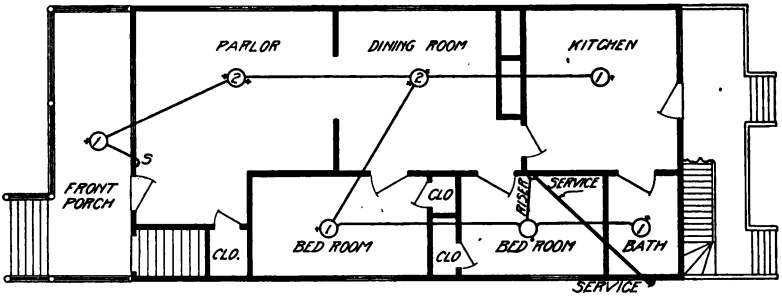


Fig. 120. Characteristic Layout for Conduits and Outlets in Small Apartment

At the point marked "riser" a main conduit rises from the "service" in the basement and on each floor has a cabinet where the supply wires for that floor are taken off and fused and where the meter may be installed. In laying out such a system of conduits or in inspecting it one should start from the service entrance cabinets from which the conduits should enter. If this cabinet contains not only the service fuses but also the sub-fuses of the branches, the several circuits should be examined to see that they are properly fused, and that they are distributed in pipes of adequate size. The several runs of conduit should then be followed throughout their entire length to see that all couplings between pipes and all attachments to outlet boxes are thoroughly tight and that both conduits and boxes are

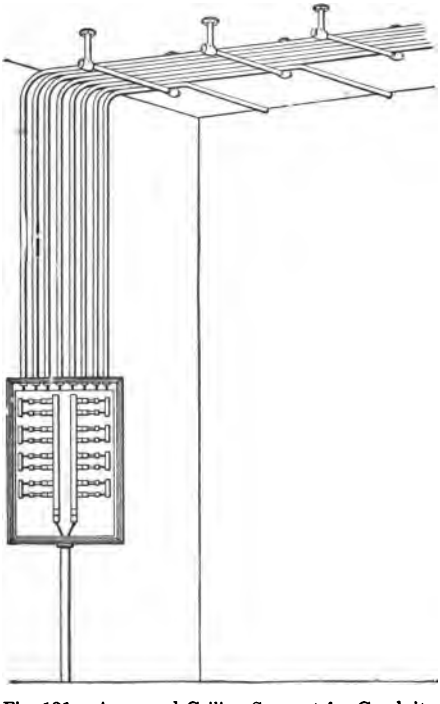


Fig. 121. Approved Ceiling Support for Conduits

fastened by straps or screws so that no strain will be put upon the screwed joints. Care should be taken to see that there are no sharp bends anywhere and that no more outlets are set in one circuit than is proper and that all are accessible. Observe whether due provision has been made for installing fuses wherever there will be a change in the size of wire. It is often cheaper and more satisfactory to continue a somewhat larger wire than is required, than to change to a smaller size and insert fuses. In no case should fuses be installed in small outlet boxes, but only in junction boxes or cabinets of ample size.

After the wires have been drawn in, observe whether it is possible to trace a given pair from outlet to outlet and if there is doubt

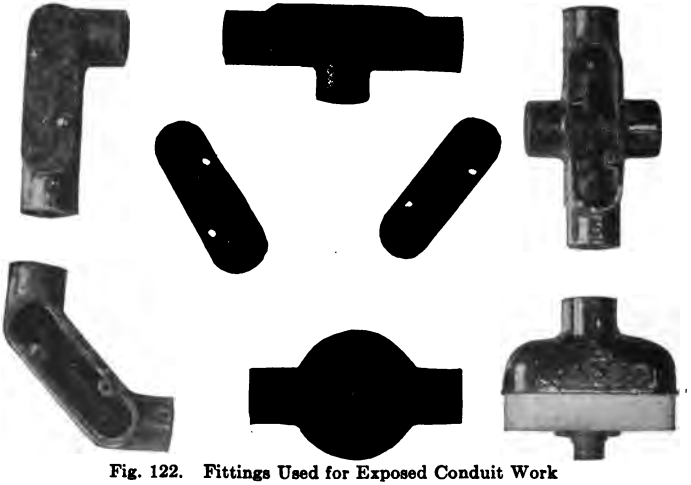


Fig. 122. Fittings Used for Exposed Conduit Work

on any point it may be necessary to demand that certain wires be drawn out for inspection. There should, of course, be absolutely no corners, Y-shaped fittings, or other devices in any place which will prevent any or all wires from being taken out and replaced at any time even after the building is completed. It is well to observe whether there are bends or traps in the piping in which water resulting from condensation or otherwise can collect. All conduit should be practically uninjured by the work done on it, all pipe ends should be threaded and reamed and the entire metal system should be firmly supported and secured so as to be free from vibration or rattle. The system must be electrically continuous throughout and must be permanently and effectively grounded.

Where conduits are run exposed, more attention should be paid to appearances. All runs should be in straight lines parallel to walls of the rooms and arranged in a symmetrical and orderly manner. Smaller sizes of conduit can usually be fastened to ceilings or walls by ordinary pipe straps, but where large conduit is used some form of pipe hanger is required and there are special patterns of a variety

Fig. 123. Conduit Wiring Circuits Laid before Partitions and Floors are Completed

of designs. Where a number of conduits are run parallel the form of supports shown in Fig. 121 is excellent. With exposed conduit a variety of fittings can be used for outlets, junction boxes, and the like, which add much to the neat appearance and also provide for joints and traps as well as for mounting sockets, switches, and other small devices. Fig. 122 shows a few such fittings for exposed conduit.

These are made with threaded nipples into which the conduit may be screwed and when so used these fittings need not be fastened to the wall or ceiling in any way, but are considered to be firmly enough held by the pipe itself. However, if boxes requiring lock nuts and screw bushings on pipes are employed they must be separately secured to the surface of wall or ceiling by screws and all cabinets of any size whatever should be so fastened. Exposed conduit work is usually employed in factories, warehouses and elsewhere if the finish of room does not require all piping to be out of sight.

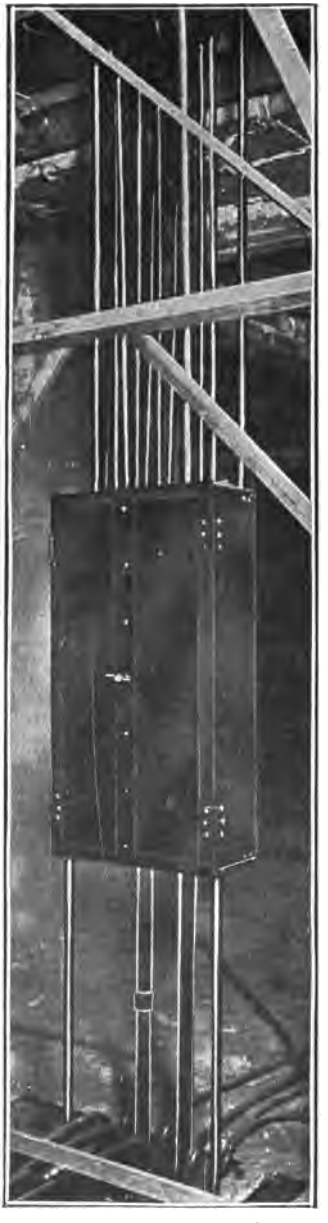


Fig. 124. Wire Distributing Cabinet

Some special problems arise in conduit work in fireproof buildings. In these types of structure the conduit work is done after the rough floor work is completed, the conduits being usually laid on the tile floors so as to be covered by the top finish of cement usually laid over the tiling. Fig. 123 shows such an installation and it will be noted that the baseboard and all side-wall outlets have been placed, before the tile partitions between the rooms, have been set. In a fireproof building it will generally be necessary to run the main risers before the floors are made and to arrange for the distributing cabinets on each floor. Fig. 124 shows a cabinet in place in the unfinished partition with two conduit risers entering it from below and the branch circuits going out from the top to various parts of the building. The cabinet in this case has been fastened by rods above and below.

In concrete buildings it is often somewhat difficult to place the conduits and the boxes so as to clear the reinforcing material and at the same time keep the metal parts well covered at all points. Special methods have to be adopted varying with the type of concrete construction employed but in all cases an effort should be made to secure proper draining of conduits. The water from the concrete

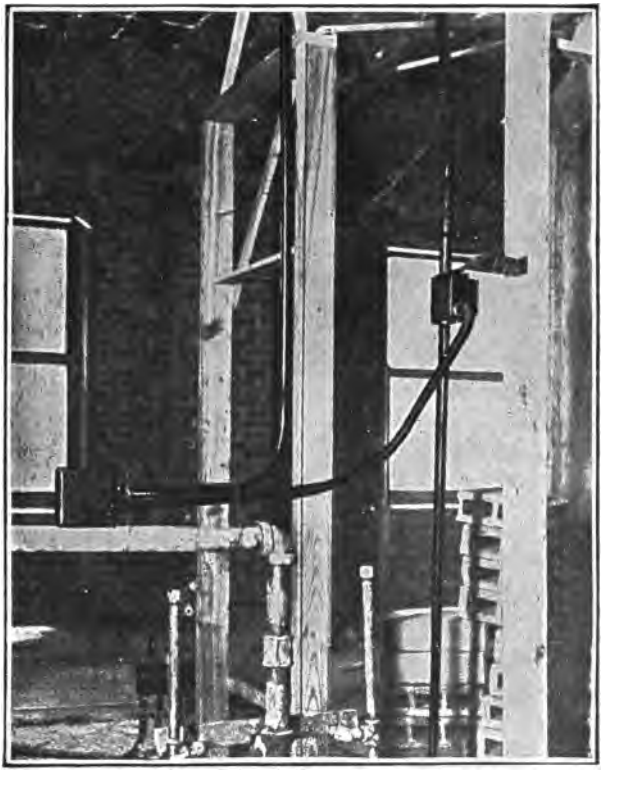


Fig. 125. Method of Placing Outlet Boxes in Tile Partitions

is very liable to get into the conduit system at the outlets or elsewhere, and when once this occurs it is difficult to get it out. Its presence is, however, most objectionable as it tends to injure the piping by rusting and also to deteriorate seriously the insulating coverings on the wires. This is a difficulty which should be considered in locating outlets in such a building and which requires very great care to entirely overcome. It is a matter of some difficulty at times

to secure outlet boxes on the concrete forms or in correct position where tile is to be used so as to be sure that they will be in the right position and firmly held when the building is completed. Ceiling boxes should be held by special hangers from each box up into the tile or concrete and reliance should not be placed on the conduits alone to hold them. Boxes set where tile partitions are to be subsequently erected should preferably be held by iron straps to adjacent steel work wherever this is practicable. Fig. 125 shows how this may be done.

SPECIAL INSTALLATIONS

DECORATIVE AND COMMERCIAL LIGHTING

Decorative Lighting. Decorative lighting by means of incandescent lamps is often desired either inside or outside buildings. The chief hazards of such work lie in the use of inferior materials hastily put together and poorly located and fused. The voltage should never exceed 150 volts in such work and not more than 1,320 watts of energy should ever be allowed to be dependent for protection upon a single cut-out. It is highly improper to take current for such systems from ordinary outlets which are wired for only small currents, since by so doing the wires to the outlets will be overloaded and the proper fuses for the wires will have to be replaced by others of too great capacity to furnish safe protection. The supply should be taken only from points on the circuit (as at distribution boards or panels) where the correct fusing and wiring can be provided for.

There is obviously no real distinction between *decorative* lighting and *ordinary* lighting arrangements except that the former is usually put up for temporary use only. If these temporary circuits are installed in a workmanlike manner and if good wire and good sockets are used there need be no special hazard provided the wires are not tacked up in a manner liable to injure the insulations and are not made to serve as supports for inflammable decorations of cloth or paper. Festoons of keyless weatherproof sockets well connected to standard rubber-covered wire (not flexible cord), and kept separated from all combustible stuff, do not present any great hazard but no such installation should be made without great care and should never be allowed to remain as a permanent installation unless it is fully pro-

tected and made the equivalent of standard work in every respect. The use of extra "carrier" wires for such festoons is very desirable as they remove all strain from the current-carrying wires and connections. Show windows are very frequently decorated by temporary electric displays of all sorts especially during the holiday season and such window displays are very often wired in utter disregard of all safe rules. The wires are often made to serve as supports for merchandise of very inflammable material, and where tinsel, cotton batting, and similar materials are employed, the conditions are excellent for a rapidly-spreading fire if any electric failure should occur. Incandescent lamps are often allowed to lie against inflammable materials and small motor-operated advertising or other novelties may contribute their share to the danger. The fact that an installation of this sort is "temporary" does not lessen the hazard so long as it is in operation and should not in any sense be considered as an excuse for allowing practices which are known to be dangerous. Property owners are often ignorant of the extent to which ill-advised temporary decorations jeopardize their buildings.

In show-window lighting, the lamps, whether temporary or permanent, should be placed either in the front or the top of the window, proper reflectors being used to throw the light upon the goods displayed. This plan almost invariably gives better results in lighting than lamps placed in sight, and scattered through the window and among the goods, and is also very much safer.

Outline Lighting. A very common form of decorative work consists of what is known as *outline lighting.* In this class of work rows of incandescent lamps are used on the exterior of buildings to outline the chief architectural features, to mark entrances, etc. Lamps and wiring used for such purposes inside buildings come under the regular rules for inside work but outside outline lighting may have special treatment. Only low potentials (under 550 volts) should be used and the wiring should be either open or trough work, or in conduit. Molding, either wood or metal, is not allowable since it does not afford protection against moisture. In open work the same spacing of wires from the surface (1 inch) and from each other (2½ inches) must be maintained as in all exposed wiring in damp places. If the use of flexible tubing is necessary, as at crosses or where regular spacing cannot be maintained, the ends of the tubing must be sealed

and painted so as to exclude moisture, and for a similar reason armored cable, if used, must be of the type having a lead sheath over the conductors and under the armor.

In order to assure proper control and fusing of outline-wiring circuits they should have their own separate switch and fuses enclosed in a suitable metal cabinet which must be watertight if placed out-of-doors. Small candle-power lamps (2 to 4) are almost always used for outline wiring and may be so grouped on the circuits that not more than 1320 watts will be dependent on a single pair of fuses. This limitation of the amount of wattage to be carried by a single circuit is to prevent any trouble in a single socket causing too much arcing or burning before the fuse protecting its circuit will open. All the sockets and receptacles in outline wiring must be of the keyless porcelain type and the wires connecting them must be soldered to the lugs. With conduit work in outline wiring special attention should be given to making the entire system as water tight as possible. The receptacles set in the covers of steel outlet boxes or *conduits* should be provided with rubber gaskets, and similar rubber rings may also be used to advantage about the bases of the lamps to prevent the entrance of water into the receptacles themselves.

Electric Signs. An endless variety of electric signs are shown on the streets of cities and towns today, from the simplest illuminated panels to huge structures containing many hundreds of lamps and operated by very complicated "flashing" machines. An elaborate treatment of all types of signs cannot be given here. The large signs erected on roofs should come under the supervision of the building department of a city or under both electric and building departments. Many of these signs are hazardous because of the obstruction they offer to firemen, the large amount of power they use, and the inadequate provision made for cutting off current from them either automatically or by hand switches in accessible places. No combustible material should be permitted either in or near such signs.

It is preferable that all the wiring be in conduit but where this is impracticable, the supports and spacing of wires should be excellent and the sides of the circuits should be kept apart preferably by bunching all wires of one polarity into cables covered by waterproof and slow-burning jackets. The mass of inflammable rubber-covered

and braided wire necessary for a large sign requires skilful arrangement to avoid a serious blaze in case of failure.

Signs of every size should be "all metal," sheet steel being not less than No. 28 U. S. gauge and frames being in all cases of ample stiffness and strength. Metal parts should be well protected by paint or enamel and the sign structure should be reasonably water tight but have drainage holes in the bottom to let out any water that may collect inside. The wires should be soldered to all receptacle terminals, should be rubber-covered, double-braided, and brought out through the sign structure either in conduit or in well spaced porcelain bushings with drip loops. In supporting the sign attention should be paid to preventing wear or abrasion of the leading-in wires by swinging of the sign. Many cities have especially elaborate rules for the placing and supporting of signs designed to reduce the possibility of their falling or of their interfering too much with the use of fire-escapes or the work of firemen in case of fire in the building.

Sign Flashers. The flashing, and other very elaborate effects of electric signs, are accomplished by the use of what is known as sign-

Fig. 126. Sign Flasher for Displaying Electric Signs

machines or flashers, Fig. 126, which consist essentially of motor-driven drum switches often of great size and complexity. These machines are hazardous chiefly from their use of many necessarily rather frail single-pole brush switches with large numbers of connecting wires leading to them and from the fact that being essentially automatic, such machines are liable to be neglected and poorly maintained. The location of a sign machine should be such as to remove it from the chance of accidental injury or tampering, to permit the direct and well arranged running of circuits to it, and to render it accessible for cleaning, adjusting, and inspecting at all times. A flasher should never be installed in a closet or other concealed space. If it is impracticable to mount it outside the building near the sign, as is preferable, a location should be chosen that

will reduce as far as possible the amount of wiring required. A platform or shelf over a doorway and just inside the building is often the best place available. A heavy metal cover must be provided but this should be removable so as to permit adjustment of all operating parts within.

THEATER WIRING

General Specifications. The electric equipment of theaters is of great importance both because of the large value of these properties and also because of the life hazard involved in any public building in which large numbers of people assemble. The electric equipment of a modern theater of the first class is generally very elaborate, involving as it does not only the brilliant illumination of large rooms, the stage, and many smaller apartments, but also the power equipment for handling curtains, scenery, and other paraphernalia and the numerous devices of special character for producing stage effects. In the meaning of the Code a theater is defined as a building or part of a building in which it is designed to make a presentation of dramatic, operatic or other performances or shows for the entertainment of spectators, which is capable of seating at least 400 persons, and which has a stage for such performances that can be used for scenery and other appliances. All theater wiring not specifically covered by special rules should conform to standard rules and requirements for work of its class. The special rules naturally divide into those which concern the protection of life chiefly and those which concern primarily the fire hazard, though, of course, the latter have a direct bearing on the life hazard also, since even a relatively small fire in a theater may produce a panic resulting in injury to many persons.

For the purpose of insuring the most reliable maintenance of proper lighting and consequent safety and freedom from panic in the audience, the underwriters' rules suggest that where the source of electric supply is outside the building there must be at least two separate and distinct services where practicable, fed from separate street mains, one service to be of sufficient capacity to supply current for the entire equipment of the theater, while the other service must be at least of sufficient capacity to supply current for all emergency lights. By "emergency lights" are meant exit lights and all lights in lobbies, stairways, corridors, and other portions of

the theater to which the public have access which are kept normally lighted during the performance. Where source of supply is an isolated plant within the same building, an auxiliary service of at least sufficient capacity to supply all emergency lights must be installed from some outside source, or a suitable storage battery within the premises may be considered the equivalent of such service.

The principal hazards in a theater result from the stage equipment since it is there rather than in the auditorium that large currents are used; many conductors are required, and all sorts of special devices are employed often in close proximity to combustible material such as scenery. Furthermore, the constant changes, additions and special requirements for different productions result in subjecting the electric equipment to exceptionally hard wear and tear on theater stages so that proper upkeep can be secured only by the use of the most approved materials and methods and constant re-inspections. All permanent electric work on the stage side of the proscenium arch must be in conduit or armored cable except in border lights and on the stage switchboards.

All of the stage circuits, footlights, borders, arc lamps, and usually all house lighting are controlled from a switchboard located on the stage at one side of the proscenium arch. This results in a very large number of cables and wires being concentrated at this board and calls for very careful planning if anything like safe and orderly arrangement is to be secured. The space available is often small and circuits are, therefore, liable to be unduly crowded and confused. The design of a large stage switchboard calls for no little engineering skill, which is too often noticeable chiefly from its entire absence especially in older houses. The space back of the board should be of ample size, readily accessible but entirely enclosed by absolutely fireproof walls and doors and preferably directly ventilated to the outside by a special brick chimney or large flue. All circuits should be controlled by substantial knife switches and fused by standard enclosed cut-outs in accessible places where their operation will not in any way be liable to set fire to the wire insulations. It is very desirable that all wires on the back of the board be covered with asbestos jackets and be well spaced.

Dimmers. The *dimmers* or special rheostats for gradually reducing the intensity of incandescent lamps either in the auditorium

or on the stage constitute often a very large installation of heat-developing apparatus which should be carefully located on iron brackets or on open galleries absolutely separated from any possible contact with burnable stuff. Fig. 127 shows a bank of dimmers.

Footlights and Borders. Among the more important fixed-appliances are the *footlights, border and strip lights,* and the *stage-floor pockets.* The footlights should be installed either in conduit or on special steel boxes which entirely enclose the lamp receptacles. Border lights must be substantially made of heavy sheet metal (at least No. 20 metal gauge) and must be wired with slow-burning wire because they necessarily get very hot from the lamps they contain.

Fig. 127. Bank of Theater Dimmers

Footlights, on the other hand, do not get so hot and their location makes them susceptible to moisture during the cleaning or washing of the floor of the stage. They should, therefore, be wired with rubber-covered wire.

Border lights must be raised and lowered and, therefore, current must be carried to them by means of cables composed of stranded rubber-covered wires. Such cables should be in rigid conduit to the point where the cable leaves for the border and at this point a suitable junction box should be provided. The method of bringing the cable from this box and also of leading it into the border structure should receive special attention to prevent undue strain being brought to bear upon it at these connections. The cable should be of the

special type designed for this service. Figs. 128 and 129 show sections of footlights and borders ready for installation on a stage.

Fig. 128. Section of Theater Footlights

Stage Pockets. Stage pockets (see Fig. 130) are iron boxes, having trap doors flush with the stage floor and containing receptacles

Fig. 129. Section of Theater Borders

for special plugs and cables by means of which arc lamps, flood lamps, and other temporary and portable devices may be connected. The circuits should have a capacity of at least 35 amperes for arc lamps or 15 amperes for incandescent lamps, wired to the full capacity and controlled from the stage board. They should contain no fuses and should be so constructed that accumulations of dust or rubbish in them cannot interfere with their safe use or be liable to cause

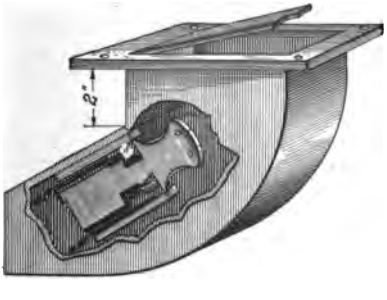


Fig. 130. Stage Pocket

a fire from any arc resulting from withdrawing the plug. These pockets may be for one or several plugs.

Portable equipments for use on theater stages include, in addition to special devices of all sorts—arc lamps, bunch lamps, strip lights, pin plug connectors, and portable plugging boxes. Fig. 131 shows a poor form of stage arc lamp of the type supposed to have caused the Iroquois theater fire in Chicago, while Fig. 132 shows a

Fig. 131. Non-Approved Form of Stage Arc Lamp

Fig. 132. Approved Form of Stage Arc Lamp

modern approved form. These should be of approved pattern, made of non-combustible materials only and fitted with standard stage cable the specifications for which are as follows: To consist of not more than three flexible copper conductors each of capacity

not exceeding No. 4 B. & S. gauge, built up of wires not smaller than No. 26 B. & S. gauge; each conductor to be covered with a cotton wind and with rubber insulation of thickness equivalent to standard rubber-covered wire and a saturated braid; the conductors to be twisted together with a filler (jute or a similar material) to make the cable round and to act as a cushion; the whole to be covered with two weatherproof braids. Such a cable will withstand considerable hard usage and has sufficient mechanical strength to endure the severe conditions of this service.

Special Lighting Circuits and Stage Effects. The proper installation of all of the stage devices just mentioned is such an important feature of the safety of the theater that special rules are established for portable conductors, for lights on scenery, for festoons, and for the many special effects, such as lightning, etc.

Requirements for Stage Auditoriums. The special requirements for the lighting of stage auditoriums are as follows: All wiring must be in either conduit, metal moldings, or armored cable; all fuses must be in enclosed cabinets; exit lights must not have more than one set of fuses between them and the main service fuses, and together with all hall and corridor lights, must be supplied independently of the stage lighting and be controlled only from the lobby or front of the house. All of these requirements are made to insure adequate lighting for the audience in case of a fire, to render the exit and corridor lights independent of any accident to circuits resulting from a stage fire, and to insure a certain amount of illumination at all times in order to permit firemen to work to advantage in case of a fire in the auditorium or corridors leading thereto.

MOVING PICTURE THEATERS AND MACHINES

Interior Equipment. The very large number of moving-picture theaters which have come into use in the past few years has introduced a special hazard of considerable extent and a large number of disastrous fires in such installations have been recorded. See Fig. 133. These theaters have often been established in rooms originally intended for stores and their equipment has been of the poorest character. This condition is now somewhat improved as the danger has become more generally recognized and has been made the sub-

ject of special legislation both by insurance interests and by municipal and town ordinances.

Causes of Danger. The lighting of such theaters comes under the ordinary rules for electrical work but the peculiar danger lies

Fig. 133. Showing Fire in Moving Picture Lantern Housing Due to Inadequate Precautions

in the use of the arc lamp projection machines with the highly inflammable "films" on which the pictures are printed. These films

are of cellulose coated with a chemical which burns with great intensity and rapidity and with an almost explosive force. A burning film cannot be extinguished easily and evolves an enormous amount of heat and a dense and suffocating smoke. In displaying the moving pictures the film (usually 500 to 1,500 feet in length) is caused to pass rapidly in front of a special arc lamp taking from 25 to 50 amperes at 110 volts, the light and also the heat of the arc being concentrated on a small area of the film about as large as a postage stamp by means of lenses set in the head of the machine. While the machine is in normal operation, the ribbon of film is moved so rapidly that no portion of it has time to become heated. If, however, for any cause, the advance of the film is checked so that a portion of it remains for even a few seconds exposed to the concentrated heat of the arc, it is at once ignited and the flame spreads to the adjacent parts of the film and the whole reel is liable to burn up with a very intense fire which may endanger the life of the operator and create a serious fire hazard to the building. The film may also be ignited by coming into contact with the hot lamp housing or with the resistance box which it is usually necessary to use in the arc lamp circuit to regulate the current.

The arc lamp and rheostats should be constructed similarly to arc lamps and rheostats used on theater stages. Tight metal boxes made without solder must be used both to hold the reel from which the film is unwound in order to expose to view, and also to receive the film after it has passed through the machine head, and the openings in these boxes must be as small as possible, being regulated by rollers between which the film may pass or by shutters which can be instantly closed. The handle or crank used in operating the machine must be secured to the spindle or shaft, so that there will be no liability of its coming off and allowing the film to stop in front of the lamp. A shutter must be arranged in front of the condenser, so as to be readily closed. Extra films must be kept in a tight metal box. Machine may be driven by hand or by motor, but in the latter case the machine must be expressly designed and approved for such operation and must be in charge of a skilled operator. Special permission to use motor-driven machines is also required. Hand-driven machines must not be converted into motor-driven machines by the addition of an ordinary motor since some special

and additional protective features are required in motor-driven machines, chiefly because with them the operator is able to run the machine with less constant attention. It is very essential that the film and the entire equipment receive the constant attention of the operator. The picture machine must be placed in an enclosure or house made of suitable fireproof material, thoroughly ventilated, and large enough for the operator to walk freely around the machine. All openings into this booth must be arranged so as to be entirely closed by doors or shutters constructed of the same or equally good fire-resisting material as the booth itself. Doors or covers must be held normally closed by spring hinges or equivalent devices.

The construction, location, and wiring of this booth are the chief considerations in the equipment of a moving-picture theater and no pains should be spared to obtain the highest possible degree of security in its construction, equipment, and maintenance.

CAR WIRING

The electric wiring of cars requires some special rules which make certain exceptions to the general rules on the one hand and which make some special extra requirements on the other hand. These special rules have to do chiefly with the protection of car bodies and woodwork over all the electrical apparatus such as motors, resistances, contactors, and the like, and over such of the conductors as are not run in conduit. Other somewhat special requirements apply to wires, cables, and methods of making joints and connections in them, to the location and type of fuses and circuit breakers to be used, to special forms of conduit and wood molding, and to details of the lighting, heating, and air-pump circuits. Very carefully detailed requirements have been worked out for the main motor circuits and for the devices used in connection with them. As all of these requirements are of a very special character, the underwriters' rules in this connection should be studied in detail by those directly interested in car wiring.

Car houses or barns present some hazards which can be reduced by the observance of a few special rules which are determined chiefly by the fact that the railway circuit is normally grounded and thus requires somewhat different treatment from the ordinary underground light or power circuits.

LIGHTING AND POWER FROM RAILWAY WIRES

It should be especially noted that under no circumstances is it proper to take lighting or power circuits from trolley or third-rail railway circuits with a ground return. This, of course, does not and cannot apply to the electric railway cars, car houses, power, passenger and freight houses connected with the operation of electric railways in which the use of such circuits is obviously necessary and which can be specially guarded and supervised. For all other factories or buildings of all sorts, power from grounded railway circuits is forbidden because of the danger of introducing into a building a circuit which has so much capacity back of it and which is thoroughly connected with the earth on one side. The inevitable fluctuation in voltage would also frequently require overfusing of the lighting circuits to prevent blowing fuses under normal conditions.

HIGH- AND EXTRA HIGH-POTENTIAL SYSTEMS

Classification. Under low, constant-potential systems are included all such as have voltages not over 550 volts but it should be noted that this distinction is an arbitrary one adopted for the classification of the rules on electrical work in relation to the fire hazard and is not made in just this way in classifying power-transmission lines and commercial systems from other viewpoints. In the underwriters' rules any circuit attached to any machine, or combination of machines, which develops a difference of potential, between any two wires, of over 550 volts and less than 3,500 volts, shall be considered as a high-potential circuit and as coming under that class, unless an approved transforming device is used, which cuts the difference of potential down to 550 volts or less. Similarly if the difference of potential between any two wires is over 3,500 volts the circuit is classed as an extra high-potential circuit unless an approved transforming device is used. This means that where the power is brought to a transformer on primary lines of not over 3,500 volts and the secondary lines are not over 550 volts, the secondary system of light or power is considered a low-potential system, but if the primary wires of 550 to 3,500 volts are direct to the power-consuming devices, as motors, without the outside transformer, the system is considered a high-potential system. If the primary lines are over 3,500 volts, the secondary lines beyond the transformers

are classed as high-potential and where no transformer is employed the circuit is extra high-potential.

High- and extra high-potential systems are, of course, usually alternating-current circuits since only alternating current is ordinarily used for over 600 volts. There are, however, a number of railway installations in the United States operating at 1,200 volts direct current and this type of power distribution is becoming somewhat common. A 1,200-volt circuit is, of course, classed as high-potential. Use is made of high-potential circuits for both light and power purposes and its advantages over low voltages lie in the smaller sized copper that can be used to transmit a given amount of power over a certain distance with a specified percentage of loss due to the line wires.

Requirements for Safety. For lighting, 2,200- to 2,500-volt circuits are used to transmit the power from the generating station to standard transformers at or near buildings where the light is used and these transformers step down the voltage either to 110 or 220 volts or to a three-wire 110- to 220-volt system on the secondary side for the lamps. A very few cities and towns employ a 220- to 440-volt three-wire secondary system but this is not usual or desirable in general, as most fittings, fuses, etc., are designed for not over 250 volts.

Motors designed for alternating current may, of course, be operated on these secondaries and such secondary circuits whether for light or power are simply low-potential circuits provided the higher voltage lines end at transformers suitably installed outside the buildings or as near as possible to the point where the primary wires enter the buildings. The outside location is much to be preferred.

When circuits having high-potential transformers are located inside of buildings they should be placed in an enclosure made of fire-resisting material such as brick, tile, or concrete. The enclosure should be used for nothing but the transformers and should be kept locked. Fig. 134 shows such an enclosure or vault for transformers. It is a good plan to arrange the transformer room or enclosure so that it can be entered only from outdoors, since then, even if the door should happen to be open at the time of a fire in this room, it is probable that no especial harm would be done. Moreover, the fire

could doubtless be better handled from the outside. The transformers must be thoroughly insulated from the ground, or permanently and effectually grounded, and the enclosure in which they are placed must be practically air-tight, except that it must be

Fig. 134.* Approved Method of Protecting Transformers in a Vault

thoroughly ventilated to the outdoor air, if possible through a chimney or flue. There should be at least six inches of air space on all sides of the transformer. This rule will permit of either the insulating or grounding of transformer cases as seems most advisable under the conditions, but will require that with either arrangement the work

Courtesy Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass

be well done, and that unless good insulation be provided the cases be definitely grounded. The object of an air-tight enclosure is to prevent smoke from escaping or fire from spreading, in case the transformer coils should become overheated from an overload or should be ignited by a break-down in the insulation between the primary and secondary coils. This is especially important with oil-cooled transformers in which the danger from an oil-fire is added to the usual electrical hazards involved.

Wherever high-potential circuits are brought into a building only rubber-covered wire should be used and special care should be taken with the wire supports to protect the wires from mechanical injury since a failure resulting in an arc is very dangerous at this high voltage. Substantial boxing about wires on side walls and running boards where circuits cross floor timbers are very necessary, as, in fact, are all the precautions and rules for good wiring and good workmanship throughout. A very large number of motors are now used taking 2,200 to 2,500 volts at the motor terminals. Such power installations can be made reasonably safe by careful planning of the circuits and by excellence of installation and upkeep of all wiring and connected apparatus. No multiple-series or series-multiple system of lighting is allowed on high potential circuits.

Extra high-potential circuits are not allowed either in or over buildings except power stations and substations. Where extra high-potential primary circuits (over 3,500 volts) supply transformers the secondary wiring must be installed as high-potential circuits (550 to 3,500 volts) unless the primaries are installed in complete compliance with the rules governing outside work on constant-potential pole lines over 5,000 volts or are wholly underground within city, town, and village limits.

In concluding the consideration of these higher voltage circuits, it is proper to refer again to the fact that the higher the voltage employed the greater the need of care in installation, upkeep, and operation since the results of accidental arcs are more serious.

SIGNALING SYSTEMS

Wiring Requirements. The wiring and other devices in the great variety of signal systems now employed in buildings, present as a general rule no hazard except their liability to become crossed

either outside or inside buildings with electric light, heat, or power circuits. Such signal systems include telephone, telegraph, district messenger and call bell, fire and burglar alarm, and all similar appliances and circuits. It is seldom that the wires of any of these systems are installed in buildings with the same care as are those for lighting or power, and the insulations employed on signal wires are very generally far inferior to those specified for light and power circuits. Furthermore, since signal systems are usually operated from either primary or secondary (storage) batteries of low voltage and limited current capacity, they may be and commonly are installed with little attention to separation of the wires, either from each other, or from the surfaces, walls, and floors to which they are attached. It follows, therefore, that all care should be taken to prevent light and power wires carrying currents of large capacity and relatively high voltages from coming in contact with signal wires since in such event dangerous fires might very readily be caused. The same advantages in having wires underground instead of being placed on poles apply to signal as well as to light and power circuits, but the two classes should never occupy the same underground duct, manhole, or handhole even when cables are used, since in the mechanical work or repairs on the lines an injury resulting in a cross between the systems might cause a dangerous current from the higher voltage lines, to outer buildings, over the weakly insulated and poorly protected signal wires. The liability of accidental crossing of overhead signaling circuits with electric light and power circuits may be guarded against to a considerable extent by endeavoring to keep the two classes of circuits on different sides of the same street. The Code prescribes that signal wires on pole lines also carrying electric light or power wires shall generally be placed on the lower cross-arms. This arrangement is not, however, favored by many engineers or by all municipal authorities, who prefer that signal wires be put on the top arms or on extensions above the tops of the poles. The arguments in favor of putting the signal wires lowest on the poles are that they are by many judged to be more liable to break and fall, especially when loaded with sleet, because of their lesser size and strength; also in case of city fire alarm circuits which are, of course, very important, the lower position enables linemen making repairs to get at the fire-alarm wires without

passing up through the light and power wires which may be charged with dangerous voltages.

The arguments in favor of putting signal wires at the top are—they are small and, therefore, collect less ice or sleet and so are less liable to break; the light and power wires are often better insulated and a signal wire breaking is less liable to make a real live contact with them; the fall of a heavy power cable may wreck all of the signal wires if the latter are below; in the case of city fire-alarm circuits the upper location removes them from misuse and injury when wiremen are working on the other lines. However, it may be said that there is no *general agreement* either in theory or practice on this subject.

Single wires of signal circuits on the outside of buildings should have rubber insulation and where attached to frame buildings should be secured to glass or porcelain insulators or knobs. Only copper wire should be used for the span from the last pole to the building and the wires should pass through outside walls through insulating bushings and have drip loops the same as electric light wires. Inside of buildings neat arrangement and secure fastening of all wires is essential to keep them properly placed and no signal wire should come nearer than three inches to any light or power wire, unless separated therefrom by some continuous and firmly fixed non-conductor creating a permanent separation, this non-conductor to be in addition to the regular insulation on the wire as the wires would ordinarily be insulated, but the kind of insulation is not specified, as the protector described below is relied upon to stop all dangerous currents. Porcelain tubing, approved flexible tubing, or rigid conduit may be used for encasing wires where required as above. Wires where bunched together in a vertical run within any building should have a fire-resisting covering sufficient to prevent them from carrying fire from floor to floor unless they are run either in non-combustible tubing or in a fireproof shaft, which shaft should be provided with fire stops at each floor.

Signaling wires and electric light or power wires may be run in the same shaft, provided that one of these classes of wires is run in non-combustible tubing, otherwise the two classes of wires should be separated from each other by at least two inches. In no case should signaling wires be run in the same tube with light or power wires.

Protecting Devices. In signal installations where the current-carrying parts of the apparatus installed are capable of carrying indefinitely without overheating a current of ten amperes (as in some telegraph or special systems) the inside wires should be of copper at least as large as No. 16 B. & S. gauge and must have the same insulation and be supported the same as electric light or power wires for 600 volts. At the entrance to the building each wire should be protected by a 10-ampere 600-volt fuse. Such signal circuits as the above are much less common than those not suited for a 10-ampere current. Telephone, district messenger, private watchmen's time recorders, burglar alarms, and fire-alarm circuits, are never capable of carrying 10 amperes continuously and for these a special "protector" is required located as close as possible to the entrance of the building. The purpose of this protector is to prevent any foreign current or any lightning discharge from entering the building over

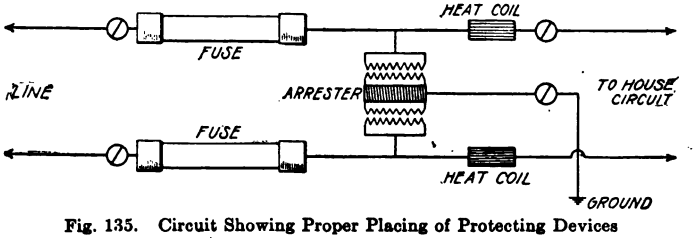


Fig. 135. Circuit Showing Proper Placing of Protecting Devices

the signal wires. For telegraph circuits this protector takes the form of a 2,000-volt fuse in each wire. The commoner "protector" such as is used on telephone lines should have the following parts mounted on a porcelain or slate base on which all parts are well insulated: a lightning arrester which will operate at 500 volts or more from a ground wire not less than No. 18 B. & S. gauge; a fuse in each side of the circuit which will blow with small currents ($\frac{1}{2}$ to 8 amperes) and will operate well on the voltages likely to reach the protector in case of accident. Where very sensitive instruments are in the circuit, such as contain magnet windings which are easily overheated, there must be a *heat coil* on each side of the line. The heat coil is designed to warm up and melt out with a current large enough to endanger the instruments if continued for a long time, but so small that it would not blow the fuses ordinarily found necessary for such instruments. The smaller currents are often called *sneak* currents. On

those telephone circuits which are supplied with current entirely from the central telephone headquarters sneak or heat coils are not

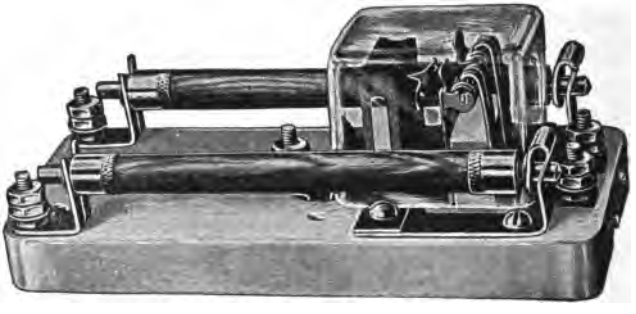


Fig. 136. Common Form of Telephone Protector

necessary. The fuses must be so placed as to protect the arrester and heat coils, and the protector terminals must be plainly marked *line, instrument,* or *ground.*

The relative arrangement of parts is shown in diagram in Fig. 135 and a common form of protector in Fig. 136.

TESTING

Where possible, two tests of the electric wiring equipment should be made, one after the wiring itself is entirely completed, and switches, cut-out panels, etc., are connected; and another one after the fixtures have all been installed. The reason for this is that if a ground or short-circuit is discovered before the fixtures are installed, it is more easily remedied; and also, because there is no division of the responsibility, as there might be if the first test were made only after the fixtures were installed. If the test shows no grounds or short-circuits before the fixtures are installed, and one does develop after they are installed, the trouble, of course, is that the short-circuit or ground is one or more of the fixtures. As a matter of fact, it is a wise plan always to make a separate test of each fixture after it is delivered at the building and before it is installed.

While a *magneto* is largely used for the purpose of testing, it is at best a crude and unreliable method. In the first place, it does not give an indication, even approximately, of the total insulation resistance, but merely indicates whether or not there is a ground or short-circuit. In some instances, moreover, a magneto test has

led to serious errors, for reasons that will be explained. If, as is nearly always the case, the magneto is an alternating-current instrument, it may sometimes happen—particularly in long cables, and especially where there is a lead sheathing on the cable—that the magneto will ring, indicating to the uninitiated that there is a ground or short-circuit on the cable. This may be, and usually is, far from being the case; and the cause of the ringing of the magneto is not a ground or short-circuit, but is due to the capacity of the cable, which acts as a condenser under certain conditions, since the magneto producing an alternating current repeatedly charges and discharges the cable in opposite directions, this changing of the current causing the magneto to ring. Of course, this defect in a magneto could be remedied by using a commutator and changing it to a direct-current machine; but as the method is faulty in itself, it is hardly worth while to do this.

A portable *galvanometer* with a resistance box and Wheatstone bridge, is sometimes employed; but this method is objectionable because it requires a special instrument which cannot be used for many other purposes. Furthermore, it requires more skill and time to use than the *voltmeter* method, which will now be described.

Voltmeter Method. The advantage of the voltmeter method is that it requires merely a direct-current voltmeter, which can be used for many other purposes, and which all engineers or contractors should possess, together with a box of cells having a potential of preferably over 30 volts. The voltmeter should have a scale of not over 150 volts, for the reason that if the scale on which the battery is used covers too wide a range (say 1,000 volts) the readings might be so small as to make the test inaccurate. A good arrangement would be to have a voltmeter having two scales—say, one of 60 and one of 600—which would make the voltmeter available for all practical potentials that are likely to be used inside of a building. If desired, a voltmeter could be obtained with three connections having three scales, the lowest scale of which would be used for testing insulation resistances.

Before starting a test, all of the fuses should be inserted and switches turned on, so that the complete test of the entire installation can be made. When this has been done, the voltmeter and battery should be connected, so as to obtain on the lowest scale of the volt-

meter the electromotive force of the entire group of cells. This connection is shown in Fig. 137. Immediately after this has been done, the insulation resistance to be tested is placed in circuit, whether the insulation to be tested is a switchboard, slate panel-board, or the entire wiring installation; and the connections are made as shown in Fig. 138. A reading is again taken of the voltmeter and the leakage is thus obtained, as it is in proportion to the difference between the first and second voltmeter readings. The explanation given below will show how this resistance may be calculated. It is evident that the resistance in the first case was merely the resistance of the voltmeter and the internal resistance of the battery. As a rule, the internal resistance of the battery is so small in comparison with the resistance of the voltmeter and the external resistance, that it may be entirely neglected, and this will be done in the following calculation. In the second case, however, the total resistance in circuit is the resistance of the voltmeter and the battery, *plus* the entire insulation resistance on all the wires, etc., connected in circuit.

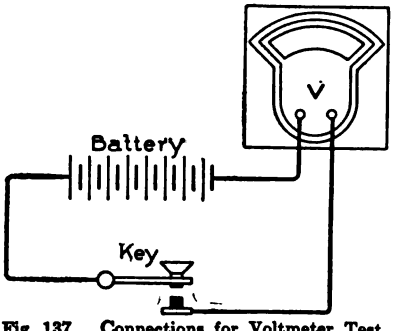


Fig. 137. Connections for Voltmeter Test Before Circuit is Connected

To put this in mathematical form, the voltage of the cells may be indicated by the letter E; and the reading of the voltmeter when

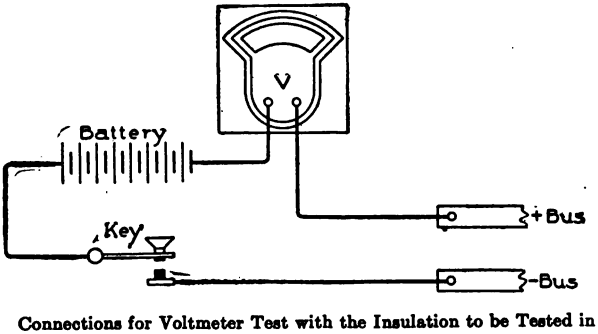


Fig. 138. Connections for Voltmeter Test with the Insulation to be Tested in Circuit

the insulation resistance is connected by the circuit, by the letter E'. Let R represent the resistance of the voltmeter and R_x represent the

insulation resistance of the installation which we wish to measure. It is a fact which the reader undoubtedly knows, that the e. m. f. as indicated by the voltmeter in Fig. 138 is inversely proportional to the resistance; that is, the greater the resistance, the lower will be the reading on the voltmeter, as this reading indicates the leakage or current passing through the resistance. Putting this in the shape of a formula, we have from the theory of proportion

$$E : E' :: R+R_x : R$$

or

$$E' R+E' R_x=E R$$

Transposing

$$E' R_x=E R-E' R=R (E-E')$$

and

$$R_x=\frac{R (E-E')}{E'}$$

Or, expressed in words, the insulation resistance is equal to the resistance of the voltmeter *multiplied by* the difference between the first reading (or the voltage in the cells) and the second reading (or the reading of the voltmeter with the insulation resistance in series with the voltmeter), *divided by* this last reading of the voltmeter.

Example. Assume a resistance of a voltmeter R of 20,000 ohms, and a voltage of the cells E of 30 volts; and suppose that the insulation resistance test of a wiring installation, including switchboard, feeders, branch circuits, panel-boards, etc., is to be made, the insulation resistance being represented by the letter R_x. By substituting in the formula

$$R_x=\frac{R (E-E')}{E'}$$

and assuming that the reading of the voltmeter with the insulation resistance connected is 5, we have

$$R_x=\frac{20{,}000 \times (30-5)}{5}=100{,}000 \text{ ohms}$$

If the test shows an excessive amount of leakage, or a ground or short-circuit, the location of the trouble may be determined by the process of elimination—that is, by cutting out the various feeders

until the ground or leakage disappears, and, when the feeder on which the trouble exists has been located, by following the same process with the branch circuits.

Of course, the larger the installation and the longer and more numerous the circuits, the greater the leakage will be; and the lower will be the insulation resistance, as there is a greater surface exposed for leakage. The rules of the Code give a sliding scale for the requirements as to insulation resistance, depending upon the amount of current carried by the various feeders, branch circuits, etc. The rule of the Code covering this point, is as follows:

The wiring in any building must test free from grounds; *i. e.*, the complete installation must have an insulation between conductors and between all conductors and the ground (not including attachments, sockets, receptacles, etc.) not less than that given below:

Up to	5 amperes	4,000,000 ohms
Up to	10 amperes	2,000,000 ohms
Up to	25 amperes	800,000 ohms
Up to	50 amperes	400,000 ohms
Up to	100 amperes	200,000 ohms
Up to	200 amperes	100,000 ohms
Up to	400 amperes	50,000 ohms
Up to	800 amperes	25,000 ohms
Up to	1,600 amperes	12,500 ohms

The test must be made with all cut-outs and safety devices in place. If the lamp sockets, receptacles, electroliers, etc., are also connected, only one-half of the resistances specified in the table will be required.

DEVICES AND MATERIALS

No care in installing electrical equipments will entirely compensate for the use of inferior or defective devices or materials. The National Board of Fire Underwriters has for many years maintained a system of tests and examinations of electrical appliances, and issues twice a year a "List of Electrical Fittings" which contains in a classified form under the names of their manufacturers all of the standard and special fittings and materials which have been approved. These tests and examinations are made and the approvals are issued by Underwriters' Laboratories, Inc., a thoroughly equipped institution maintained in Chicago by the fire insurance interests, for the express purpose of examining and testing all kinds of devices and materials, electrical and otherwise, which have any bearing what-

soever on the fire hazard. This "List of Fittings" issued semi-annually, is universally recognized as the only complete and reliable guide to properly safeguarded electrical appliances and it should be consulted and followed in the choice and purchase of supplies. The Underwriters' Laboratories also maintain an elaborate system whereby manufacturers may obtain and place on their wares special labels issued by the Laboratories, which thus become a guarantee on the goods themselves that the articles bearing such labels are in conformity with underwriters' rules and have been examined and tested by special underwriters' inspectors at the factories where they are made. This system of label service and inspection is not yet extended to all classes of approved electrical devices, but for those classes of appliances which are now included, the label may be regarded as affording to prospective purchasers and users reliable evidence not only of the general approval of the design but also that the particular sample bearing the label is made in accordance with requirements and is suitable for use.

The constructional details of electrical fittings and materials together with the chief tests to which they are subjected, prior to approval, are contained in what is known as "Class D" of the Code. This pamphlet should be consulted for full details or inquiry should be addressed to Underwriters' Laboratories, 207 East Ohio Street, Chicago, Illinois, or 135 William Street, New York, for information not given in the Code or in the semi-annual "List of Fittings".

In the following pages is given a brief discussion of the chief characteristics and requirements of some of the more common materials and of the more important classes of devices used in electrical construction work.

RUBBER-COVERED WIRE

General Specifications. A considerable variety of grades of rubber-covered wire is manufactured, some makers offering several grades and others only one or two at most. The chief distinction lies in the quality and quantity of real new, pure, fine rubber gum used in the compound. It is not possible to determine or grade the excellence of a rubber compound by any direct or readily applied tests, but somewhat elaborate tests, physical, chemical, and elec-

TABLE IV

Thickness of Rubber Insulation

B. & S. Gauge	Thickness
18 to 16	1-32 inch
15 to 8	3-64 inch
7 to 2	1-16 inch
1 to 0000	5-64 inch
Circular Mils	
250,000 to 500,000	3-32 inch
500,000 to 1,000,000	7-64 inch
Over 1,000,000	1-8 inch

trical, are necessary to arrive at any correct estimate. The following properties of good wire may, however, be noted. The rubber should be neither hard and dry, nor soft and spongy. When examined minutely it should appear of a close uniform texture free from small bits of unmixed matter or pinholes. It should adhere closely to the tinned copper. The thickness of rubber wall should correspond to the data given in Table IV.

Measurements of insulating wall are to be made at the thinnest portion of the dielectric and it should be very carefully noted whether the copper is exactly centered in the rubber covering so that the full prescribed insulation is maintained on all sides.

The rubber insulation should exhibit a fair degree of elasticity when pieces cut from the wire are stretched and released. If the rubber breaks with a very slight pull and shows no ability to stretch and recover its first length it is probable that a very poor grade of gum has been used, or that the manufacturing process is defective, or both.

After the braid has been carefully removed it should be possible to wind the smaller sizes of wire about a cylinder of the same diameter as the rubber-covered wire without the rubber showing any breaks or cracks either at once or after several days.

The foregoing should be considered as only rough tests and not susceptible of exact application except under conditions which can be maintained in a regular testing laboratory. No directions can be given which will permit any but an expert chemist to make chemical examinations of rubber compounds.

The braids should be of close weave and should be very thoroughly saturated with the compound. All wires should have through their entire length a marker indicating by whom they were made and each coil should bear a tag giving, beside the maker's name, the maximum voltage for which it is designed, the words "National Electrical Code Standard," and the month and year when it was manufactured. Every coil of approved wire is separately tested by the maker at the factory by at least two electrical tests, one designed to show that the insulation is free from mechanical defects and the other to show at least a minimum insulation value.

Special Insulation. Most makers are prepared to furnish at a special price a grade of wire commonly known as "thirty per cent Para." This wire is understood to have an insulation containing at least 30 per cent of "fine, pure, up-river Para" gum which is much more than common commercial rubber-covered wire contains. This 30 per cent wire is also made according to certain rather exacting specifications designed to insure a high grade of insulation with good lasting properties. Wire of this description is often specified where an extra good quality is desired for first class work.

A good compound should contain a large percentage of pure, fine, new rubber of excellent quality. Para rubber is universally admitted to be the best for imparting life, strength, and durability to the insulation. The use of reclaimed rubber or any of the so-called rubber substitutes reduces the excellence of the compound approximately in the proportion in which it is used. The other ingredients of a good compound are solid, waxy, hydrocarbons, suitable mineral matter and sulphur. The sulphur plays an important part in the vulcanizing of the compound, the process whereby the rubber is transformed from its original and almost crude state into the substance familiar to us as manufactured rubber in any one of its numerous forms.

Fixture Wire. Fixtures may be wired with flexible cord or standard rubber-covered wire, and for other wires for use in fixtures, the following rules apply: The wire may be either solid or stranded and not less than No. 18 B. & S. gauge. Solid conductors must be tinned and stranded conductors must be of strands not less than No. 30 B. & S. gauge and must have a cotton wind between copper and rubber. The No. 18 wire may have a rubber insulation $\frac{1}{64}$-inch thick, but No. 16 and also flexible cord used in fixtures must have

at least $\frac{1}{32}$-inch rubber. All sizes must be covered with a good braid. The concession of so thin a rubber wall on No. 18 wire has been made because a very small wire must be used to pass through the arms and other parts of many fixtures.

In wiring certain designs of show-case fixtures, ceiling bull's-eyes and similar appliances, in which the wiring is exposed to temperatures in excess of 120° F. (49° C.), from the heat of the lamps, slow-burning wire may be used.

Insulation for Conduit and Armored Circuits. For all conduit work and in all armored cable the wire is regular standard rubber-covered with an extra braid. For twin or duplex wires, this outer braid, which should be at least $\frac{1}{64}$-inch thick, is made as a covering over the two regular rubber-covered and braided conductors. These twin wires are generally used in conduit work but where single conductors are used they must also have double braid. The purpose of this extra outer braid is primarily to withstand the abrasion and strain resulting from hauling the conductors through the conduits from outlet to outlet, and the braids on the individual conductors are to hold the rubber insulation in place and prevent jamming and flattening which might reduce the thickness of rubber between the two wires and thus weaken the insulation at many points.

RIGID CONDUIT AND CONDUIT FITTINGS

Unlined Steel Conduit. The following description applies only to standard unlined steel conduit. This is made of mild steel with a butt weld joint lengthwise of the pipe. Sizes run from normal $\frac{1}{2}$-inch to 4-inch pipe. The raw pipe is thoroughly cleaned inside and outside and then given a protective coating either of an enamel baked on or of zinc applied either by electroplating or by a special process known as sherardizing. With either form of zincing the interior is given a coat of enamel also. The finished pipe should be smoothly coated and able to stand bending without injury to the enamel or the zinc. The conduit should be of sufficiently true circular section to admit of cutting true, clean threads. The enamel applied to conduit is not considered as an insulation but either enamel or zinc is required to protect the steel from rusting away and also to give a smooth surface for the conductors to be drawn over in inserting the wires. Ordinary commercial pipe should never be used as electric conduit since it is not free from rough edges, is not maintained at

TABLE V

Minimum Weights of Conduit for Required Wall Thickness

Size Inches	Pounds per 100 Feet	Size Inches	Pounds per 100 Feet
½	79	1½	249
¾	105	2	334
1	153	3	690
1¼	201		

uniform size or wall thickness, is not protected against rust and in general is not made with the care and rigid inspection which have been found by experience to be necessary for electric conduits. Table V gives the minimum weights per 100 feet of finished conduit which are required to give the specified thickness of wall.

Conduit Fittings. A very great variety of boxes and small fittings for use with conduit is available. All boxes including flush switch boxes should be either of cast iron with walls at least ⅛-inch thick or of sheet steel at least .078 inch thick. They must be well enameled or galvanized to protect them from rusting and must have no openings not closed by the entering pipes, by a metal cover of the same thickness of the box or by the switch, receptacle, or canopy of the device attached to them. Under no circumstances is it allowable to place any such box so that it will not be accessible. There should be no rough edges or corners which are liable to injure the coverings of wires as they are drawn in. Fig. 139 shows the form of a common type of box. Boxes for use with combination gas and electric fixtures must be provided with an arrangement for making a tight electrical connection between the box and the gas pipe at each outlet so that there may be no arcing between box and pipe in case any failure of wire insulation causes a current to flow over the box. Otherwise such an arc may burn a hole in the gas pipe and ignite the gas. All threaded parts of boxes and all threads on bushings and metal to bushings must be clean cut and well fitted in order to insure good permanent and reliable electrical continuity of the conduit system which is one of the chief requirements for conduit work.

Fig. 139. Common Type of Conduit Box

Set screw connections have been found unsatisfactory as they loosen with the vibration of buildings and with changes of temperature, and only regular screwed thread joints or substantial clamps should be used at all conduit and armored-cable connections.

Fig. 140. Common Form of Floor Outlet Box

Where a floor outlet in a conduit system is desired, a special type of box, known as a floor outlet box, should be used, if the fitting is liable to injury or the presence of moisture is probable. Such boxes (see Fig. 140) provide ample room for making splices, for mounting receptacles or other fittings, and especially provide a substantial, water-tight top or cover set flush with the floor surface. The practice of setting flush wall receptacles in floors is allowable in hardwood floors in offices or residences where the mechanical protection need not be great and where water is never used to clean the floors.

FUSES OR CUT-OUTS

Classification. Three forms of fuses are at present employed in this country for general wiring work, *open-link* fuses, *cartridge* fuses and *plug* fuses, the last two being further described as enclosed fuses to distinguish them from the open links. The bases to which or in which the fuses are secured are called cut-outs.

Link fuses are extensively used on large switchboards and their use on such boards is open to less objection than for general wiring since such boards are usually under expert supervision and located in well-protected or fireproof rooms. With link fuses there is always the possibility of a larger fuse being put into the cut-out than it was designed for, which is not true of enclosed fuse cut-outs classified as

TABLE VI
Open-Link Fuse Spacing

	Minimum Separation of Nearest Metal Parts of Opposite Polarity Inches	Minimum Break Distance Inches
125 Volts or less		
10 amperes or less	¾	¾
11-100 amperes	1	¾
101-300 amperes	1	1
301-1000 amperes	1¼	1¼
126 to 250 Volts		
10 amperes or less	1½	1¼
11-100 amperes	1¾	1¼
101-300 amperes	2	1½
301-1000 amperes	2½	2

required below. Again, the voltage in most plants can, under some conditions, rise considerably above the normal. The need of some margin, as a factor of safety to prevent the cut-outs from being ruined in ordinary service, is therefore evident. When tablet-boards or single fuse-blocks with such open-link fuses on them are used in general wiring, they must be enclosed in cabinet boxes. This is necessary, because a severe flash may occur when such fuses melt, so that they would be dangerous if exposed in the neighborhood of any combustible material. Link fuses should never be mounted on porcelain cut-outs because a severe short-circuit is liable to break this rather fragile material and the molten metal is apt to fuse into the porcelain, partly reducing its insulating properties.

There is no filler surrounding the fusible metal of open links and, therefore, the ability of the fuse to open the circuit depends on having enough of the metal burned away, when the fuse blows, to break the arc. For this reason the terminals for link fuses, as far as practicable, should be made of compact form instead of being rolled out in thin strips; and sharp edges or thin projecting pieces, as on wing thumb nuts and the like, should be avoided. Thin metal, sharp edges, and projecting pieces are much more likely to cause an arc to start than a more solid mass of metal. It is a good plan to round all corners of the terminals and to chamfer the edges. Plain fuse wire or fuse strip should never be used for links but only fuses made up with solid metal terminals as shown in Fig. 17.

In general work open-link fuses should not be used on circuits of voltages above 250 volts and where large currents are involved the use of approved circuit breakers is very much to be preferred to extra large link fuses. The spacings for open-link fuses are given in Table VI.

Plug Fuses. The form of fuse which is used in larger numbers than those of any other type, is shown in Fig. 141. Fig. 142 shows one of the many forms of cut-out bases for plug fuses and Fig. 57 shows similar blocks arranged in an asbestos-lined cabinet to make a tablet or panel-board for distributing current to branch-lighting circuits. The cabinet should have a tightly fitted asbestos-lined or metal-lined door. Plug fuses are approved for use only on circuits of not over 125 volts, including 3-wire circuits with grounded neutral, and not over 250 volts between outside wires. Fig. 143

Fig. 141. Standard Fuse Plug

Fig. 142. Cut-Out Base for Fuse Plugs

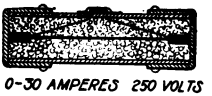
shows the effect if the fuses are blown on a 220-volt circuit. These plugs are limited to ratings of 30 amperes and less because their form and strength is not such as to make them safe for use with larger currents. They are, therefore, chiefly adapted for small lighting and motor branch circuits. They are decidedly safer than open-link fuses of equal capacity and are cheaper than enclosed cartridge fuses.

There are a number of patterns of unapproved plug fuses on the market which should be avoided as they usually lack some of the essential properties of safe fuses, although they may appear from casual inspection to be almost identical with them. It is unfortunately true that plug fuses of the present form can be "doctored" in several ways so as to carry larger currents than they should. Tinfoil, solder, and bits of copper wire are often found put around or into plug fuses so as to completely destroy their usefulness as protective devices. Inspectors and property owners should be on the lookout for this highly dangerous practice and also observe carefully whether plugs of too large current capacity have been substituted for those of

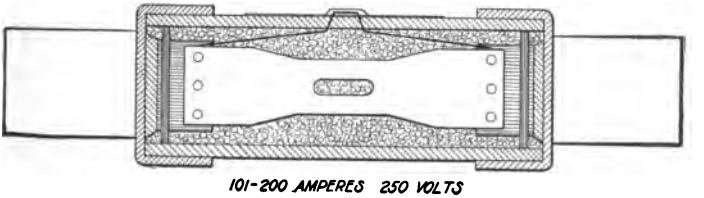
ratings which afford real protection to the wiring of the circuits of which they are a part.

Fig. 143. Effect of Plug Fuses Blown on 220-Volt Circuit

Cartridge Fuses. A cartridge fuse consists of a cylindrical tube of fiber or strong paper to which are fitted metal caps by means of which connection is made to the cut-out terminals. Within the tube is the fusible metal wire or strip extending between and firmly secured to the inside of the caps. The tube is filled with a powdered or



0-30 AMPERES 250 VOLTS

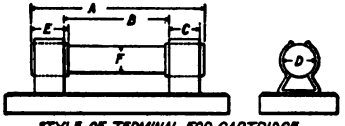


101-200 AMPERES 250 VOLTS

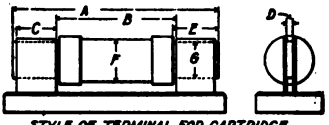
Fig. 144. Sections through Cartridge Fuses Showing Construction

granulated material packed closely about the fusible strip. The purpose of this filler is to conduct the heat from the strip to the outer

casing, to smother the arc when the fuse blows, to make it possible to adjust more exactly the carrying capacity of the fusible strip, and to absorb some of the gases evolved from the molten metal. The chief ingredients of fillers now used are magnesia and plaster of Paris. Fig. 144 shows in section the internal construction of two typical cartridge fuses of 30 and 200 amperes capacity. The illustration is full size. The small wire extending from one terminal to a point on the tube and thence to the other terminal is designed to burn off at the tube when the fuse blows and fuse a bit of powder under a slip of thin paper on the outside of the casing, thus indicating that the fuse has operated. As will be seen from the description a cartridge fuse will confine the arc, flame, or molten metal within the filler



STYLE OF TERMINAL FOR CARTRIDGE FUSES 0-60 AMPERES.
FORM 1. FERRULE CONTACT



STYLE OF TERMINAL FOR CARTRIDGE FUSES 61-600 AMPERES
FORM 2. KNIFE-BLADE CONTACT

VOLTAGE	RATED CAPACITY		A LENGTH OVER TERMINALS	B DISTANCE BETWEEN CONTACT CLIPS	C WIDTH OF CONTACT CLIPS	D DIAMETER OF FERRULES OR THICKNESS OF TERMINAL BLADES	E MIN. LENGTH OF FERRULES OR OF TERMINAL BLADES OUTSIDE OF TUBE	F DIAMETER OF TUBE	G WIDTH OF TERMINAL BLADES		RATED CAPACITY
	AMPERES		INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES		AMPERES
0-250	0-30	FORM 1	2	1	1/2	9/16	1/2	1/2		FORM 1	0-30
	31-60		3	1 3/4	5/8	13/16	5/8	3/4			31-60
	61-100	FORM 2	5 7/8	4	7/8	1/8	1	1	3/4	FORM 2	61-100
	101-200		7 1/8	4 1/2	1 1/4	3/16	1 3/16	1 1/2	1 1/8		101-200
	201-400		8 5/8	5	1 3/4	1/4	1 7/8	2	1 5/8		201-400
	401-600		10 3/8	6	2 1/8	1/4	2 1/4	2 1/2	2		401-600
251-600	0-30	FORM 1	5	4	1/2	9/16	1/2	3/4		FORM 1	0-30
	31-60		5 1/2	4 1/4	5/8	1 1/16	5/8	1			31-60
	61-100	FORM 2	7 7/8	6	7/8	1/8	1	1 1/8	3/4	FORM 2	61-100
	101-200		9 5/8	7	1 1/4	3/16	1 3/8	1 3/8	1 1/8		101-200
	201-400		11 5/8	8	1 3/8	1/4	1 7/8	2 1/2	1 5/8		201-400

Fig. 145. Dimensions and Classifications of Cartridge Fuses

and tube when its fusible element is melted by an overload or by a short-circuit and is, therefore, a safer device than an open-link fuse.

In 1905 a standardization of cartridge fuses and their cut-out bases was agreed upon in order to bring them all to uniform dimensions, to arrange the different ratings under a classification which would make it impossible to put a large fuse into a cut-out base of a smaller class, and to make it possible to use any approved fuse in any approved base whether fuse and base were of the same or different make. Under this classification two types of terminals were stand-

ardized known as *ferrule* and *knife-blade* contacts, and the current ratings were grouped into two sizes for the ferrule and four sizes for the knife-blade contacts. The dimensions and classification are fully shown on the diagrams and in the table, Fig. 145.

Knife Switches. Knife switches must always be mounted on separate bases of slate, marble, or porcelain, or on slate or marble switchboards or panels. The parts carrying the contact clips and the blade hinges must be secured to the base by two screws, a screw and a dowel-pin, or otherwise, so that the parts will always be in correct alignment. If the contact jaws or hinge clips get turned so as to be out of line, it may be impossible to close the switch, especially at the first attempt, and severe arcing may result from the efforts to do so. Even if the blade enters the jaws, the contact may be imperfect, causing undesirable heating. The chief points to note in judging a knife switch are the following: Excellence of fit of blades both at the hinge and in the contact clips; stiffness and size of all metal parts to secure good contact surfaces and ample carrying capacity. No part should become heated over 50° F. when the switch is carrying its full rated current, and at all sliding contacts there should be at least 1 square inch of surface contact for every 75 amperes of current. The cross bars should be very securely fastened to the blades and the workmanship throughout should be excellent. If each blade is secured to the cross bar by only one screw, without dowel-pins or a square shoulder fitting closely in a recess in the bar, a slight loosening of the screws will allow one blade to close and open the circuit before the other, resulting in arcing and ultimate injury to the switch. Such construction is also liable to result in a weak switch. Too little attention is frequently given the question of mechanical strength, with the result that after a comparatively short time of service the switches rattle to pieces or break unless very carefully handled, and even then repairs are often necessary to keep them in working order. A cheap switch is seldom a rugged, durable device. All switches should be marked with the name of their maker and the rating in both volts and amperes.

The spacings of switches must be at least as great as those given in the Code, a copy of which is given in the following tables. This table specifies the limits necessary for both direct-current and alternating-current systems.

TABLE VII

Approved Spacing and Marking for Knife Switches

Table 1. Not over 125 volts d. c. and a. c.
For switchboards and panel boards:—

	Width and thickness		Minimum separation of nearest metal parts of opposite polarity	Minimum break distance
	Blades	Clips and Hinges		
30 amperes	½x$\frac{1}{16}$ Inch	½x$\frac{1}{16}$ Inch	1 Inch	¾ Inch
60 amperes			1¼ Inch	1 Inch

Table 2. Not over 125 volts d. c. and a. c.
For individual switches:—

	Inch	Inch	Inch	Inch
30 amperes	½x$\frac{1}{16}$	½x$\frac{1}{16}$	1¼	1
60 and 100 amperes			1½	1¼
200 amperes			2¼	2
400 and 600 amperes			2¾	2½
800 and 1000 amperes			3	2¾

A 300-ampere switch with the spacings of the 200-ampere switch above may be used on switchboards.

Table 3. 250 volts only d. c. and a.
For all switches:—

	Inch	Inch	Inch	Inch
30 amperes	½x$\frac{1}{16}$	½x$\frac{1}{16}$	1¾	1½

Table 4. Not over 250 volts d. c. nor over 500 volts a. c.
For all switches:—

	Inch	Inch	Inch	Inch
30 amperes	⅝x⅛	⅝x$\frac{1}{16}$	2¼	2
60 and 100 amperes			2¼	2
200 amperes			2½	2¼
400 and 600 amperes			2¾	2½
800 and 1000 amperes			3	2¾

A 300-ampere switch with the spacings of the 200-ampere switch above may be used on switchboards.

Cut-out terminals on switches for over 250 volts must be designed and spaced for 600-volt fuses.

Table 5. Not over 600 volts d. c. and a. c.
For all switches:—

	Inch	Inch	Inch	Inch
30 amperes	⅝x⅛	⅝x$\frac{1}{16}$	4	3½
60 amperes			4	3½
100 amperes			4½	4

Auxiliary contacts of either a readily renewable or a quick-break type or the equivalent are recommended for d. c. switches, designed for over 250 volts, and must be provided on d. c. switches designed for use in breaking currents greater than 100 amperes at a voltage of over 250.

For 3-wire direct-current and 3-wire single-phase systems, the separation and break distances for plain 3-pole knife switches must not be less than those required in the above table for switches designed for the voltage between neutral and outside wires.

Marking. Must be plainly marked where it can be read, when the switch is installed, with the name of the maker and the current and the voltage for which the switch is designed.

Switches designed for 250-volt d. c. or 500-volt a. c. circuits, without fuses on the switch base, must be marked 250 V., d. c., 500 V., a. c. When 250-volt fuse terminals are mounted on the switch base the marking of the switch must be 250 V., d. c. and a. c. When 600-volt fuse terminals are mounted on the switch base the terminals must be spaced for 600-volt fuses and the switches marked 500 volts a. c.

Triple pole switches designed with 125-volt spacings between adjacent blades must be marked 125 volts and may be used on 3-wire d. c. or single phase systems having not more than 125 volts between adjacent wires and not more than 250 volts between the two outside wires.

When designed with 250-volt spacings between adjacent blades, triple poles switches must be marked 250 volts and may be used on 3-wire d. c. or single-phase systems having not more than 250 volts between adjacent wires and not more than 500 volts between the outside wires.

Snap Switches. Under this term are included the *common round base surface* switches, the *rotary* and *push-button* switches, which are set in boxes in side walls flush with the surface, *pendant* switches, and all such as are operated by the motion of doors, by a cord and all switches mounted on fixtures. The distinguishing feature of them all consists in the fact that the motion of the parts which open and close the circuit is produced by a spring contained in the mechanism. As the handle or button is turned or pushed this spring is wound up and at the proper tension is released, thus throwing the switch blades into or out of the contacts. Thus the quickness with which the circuit is opened or closed is not directly determined by the motion of the operator's hand but by the spring, and if the switch is of proper design and in good condition, the action is prompt and reliable even though the person using the switch is not careful to do just the right thing. Such snap switches, therefore, differ from knife-blade switches in that their proper use does not depend upon the user and they are correspondingly better suited for general purposes for unskilled persons.

The bases should be of non-combustible material, usually porcelain, and all covers should be lined with a non-conducting material such as fiber unless they are of porcelain. Without this lining there is danger of the cover forming a short-circuit in the switch, especially if the cover is removed or replaced while the switch is "alive." The side lining should extend beyond the lower edge of the cover.

The binding posts should be of a type in which the end of the connected wire is held under a screw head or equivalent device and not by a set-screw the end of which drives against the side of the wire, as a set-screw is likely to become loosened and is almost sure to cut into the wire. Indicating switches are much preferred for all work, as by showing at once whether the current is "on" or "off" they tend to save mistakes and possible accidents. The fact that lights do not burn or that a motor does not run is not necessarily a sure sign that the current is off, but the indicating switch makes it possible to tell at a glance whether the circuit is open or closed.

Fig. 146 shows a variety of approved snap switches of common type. Snap switches to be approved are required to operate successfully at 50 per cent excess current above that for which they are

rated at the voltages for which they are designed. This is to provide a margin of safety but should not be made an excuse for using them for larger currents than those marked on them. They are made in a great variety of sizes and patterns, single- and double-pole, three- and four-way, and in special designs for turning on the lamps of a chandelier one after the other or for controlling small motors or heating devices. The standardized ratings include 125, 250, and 600 volts for currents of 3, 5, and 10 amperes in the more commonly used patterns. Certain large-sized double-pole surface snap switches are rated at 20 or 30 amperes while a few of the more special and less substantial forms are limited to 1 ampere only. In judging snap

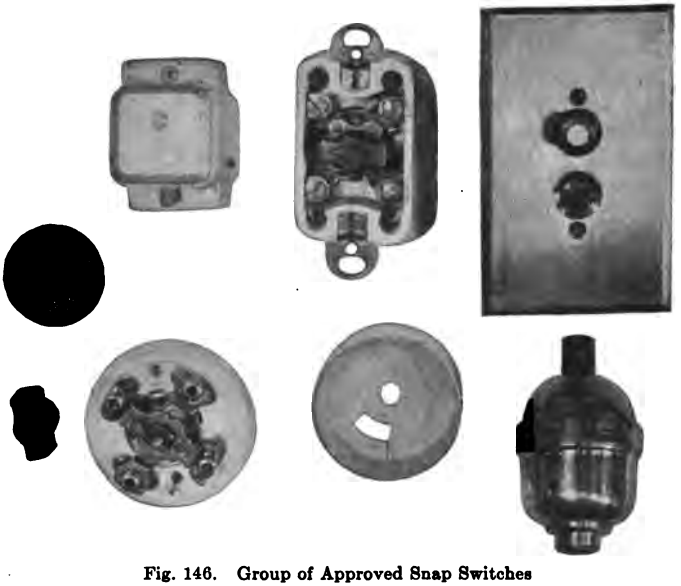


Fig. 146. Group of Approved Snap Switches

switches of all kinds samples are tested by Underwriters' Laboratories in the following way: they are connected to control groups of lamps taking full rated current of the switch at full rated voltage and are then put on a special machine which operates them slowly and continuously for 6,000 cycles, that is 6,000 full "on and off" operations. It is required that the samples stand this endurance test without failing either mechanically or electrically. This test is re-applied to new and recent samples from time to time, and similar

tests are constantly in progress at the factories where the switches are made, so that any important defect in material or construction is soon detected and a fairly uniform grade of snap switches is sure to be produced for the user. Such persistent tests have done much to improve the quality of these and other electrical products.

CIRCUIT BREAKERS

Circuit breakers are automatic switches so designed that an excess current will cause the switch to open. They thus share the properties of both switches and protective devices such as fuses, and in their choice and installation both functions must be considered. Breakers are made for currents of all capacities and for circuits of every voltage both d. c. and a. c. Those most commonly used on lighting and power switchboards and in general commercial work are for voltages of 600 volts or less (occasionally 2,000 volts). For higher voltages the breakers are of massive form and are often set in *cells* or compartments of brick, slate, or concrete. Such breakers are employed only where expert supervision is always available and their form and operation is, therefore, not prescribed by underwriters' rules but rather by the engineering necessities of the system of which they are a part.

The ordinary commercial breaker as used on low-voltage circuits may be one, two, or three poles and these may be independent of each other or may be interlocked so that an overload on any one wire will cause all the lines to be opened. The latter is preferable. Breakers are usually made with an adjustment regulating the point at which they will open. Thus a 100-ampere breaker may be set to open at any current with a certain range above and below 100 amperes.

In installing breakers the same care should be taken as with fuses of like capacity. They should never be placed near any inflammable material, as their operation under severe overloads results in a severe though brief arc and often in the spattering of bits of molten metal quite capable of igniting waste, shavings, etc. The use of circuit breakers instead of fuses is to be recommended for very large currents and for all circuits such as many motor circuits where operating conditions are liable to produce frequent overloads.

Classification. Circuit breakers may be divided into two chief classes, *carbon* or *air-break* patterns and *oil-immersed* patterns. The

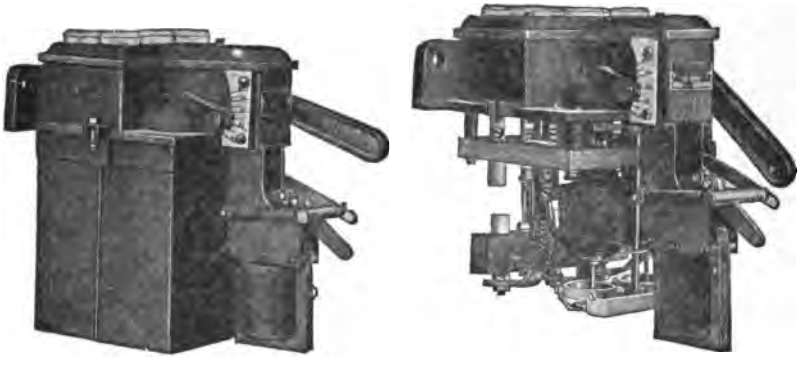


Fig. 147. Modern Oil Circuit Breaker

former may be used on either d. c. or a. c. circuits. They have copper blades and fixed contacts with carbon secondary contacts arranged to open just after the heavy copper contacts. Thus the current is carried by copper parts of ample size when the breaker is closed, and the arcing on opening is largely confined to the carbon contacts which are better for this purpose than metal. Such breakers may become dangerous either from overheating of the coils, from

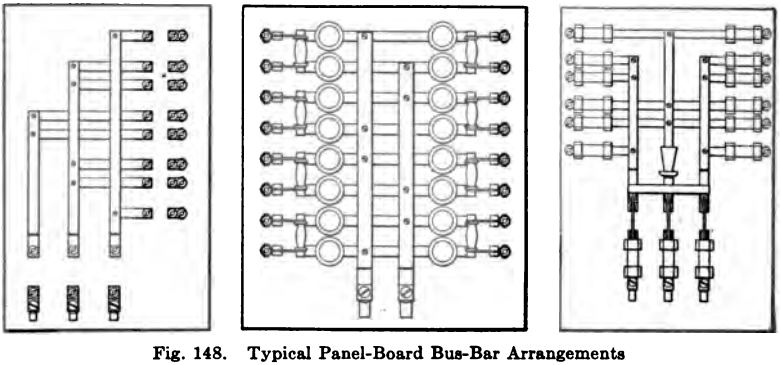


Fig. 148. Typical Panel-Board Bus-Bar Arrangements

arcing upon opening heavy currents, or from failure to act in emergency as they are intended to do. However, the better types of modern breaker are very well made and form reliable protective devices.

Oil-immersed breakers are coming more and more into use. They are made with their contacts immersed in a heavy oil contained in a can or case of suitable form. When the contacts open, the oil aids very greatly in quenching the arc, and such breakers can, therefore, be made quite compact since a long break distance is not so essential. These breakers are made both for switchboards and wall mounting. They are not so well suited to direct-current circuits since the action of the d. c. arc carbonizes the oil too rapidly. Fig. 147 shows a modern oil breaker. They present a hazard due to the oil which may become overheated or even ignited. This is unlikely to occur with a well designed oil switch or breaker, but the usual precautions should be taken to keep the switch and its immediate neighborhood clean and free from accumulations of rubbish or any inflammable material which may become oil soaked.

MISCELLANEOUS DEVICES

Panel Boards and Cabinets. Panel boards are distributing boards, or switchboards from which the branch circuits are led off from the mains. They must have slate bases on which are mounted the necessary bus bars, switches and fuses. A very great variety of panels is made, the arrangement of parts in a few patterns being shown in Fig. 148, while a complete panel set in a steel cabinet is shown in Fig. 149. Fig. 150 shows the wiring channel often provided and a cabinet with wood door and trim. The panel base and the two partitions shown in the section drawing are of slate and all other interior surfaces of the cabinet including the door should be lined with sheet steel.

Wood cabinets should not be used on conduit, armored cables, or metal molding systems of wiring as they do not form a metallic connection between parts of the system and any attempt to overcome this by bonding around the box by wire is not liable to result in a good job. Metal cabinets are preferable in all cases except possibly in very damp locations where they are liable to rust rapidly. All cabinets whether for panels or for individual switches or cut-outs should be thoroughly dust tight and fitted with tightly-closing doors. No metal thinner than No. 16 U. S. Metal Gauge should be used and heavier metal is necessary for all but the smaller sizes of box to secure the requisite stiffness and durability.

Sockets and Receptacles. The almost endless variety of these fittings may be classified in various ways, as for dry or for wet places; key and keyless types; brass shell or porcelain types; conduit boxes; molding signs; miniature and candelabra sockets and receptacles, etc. All standard sockets and receptacles are now made with what

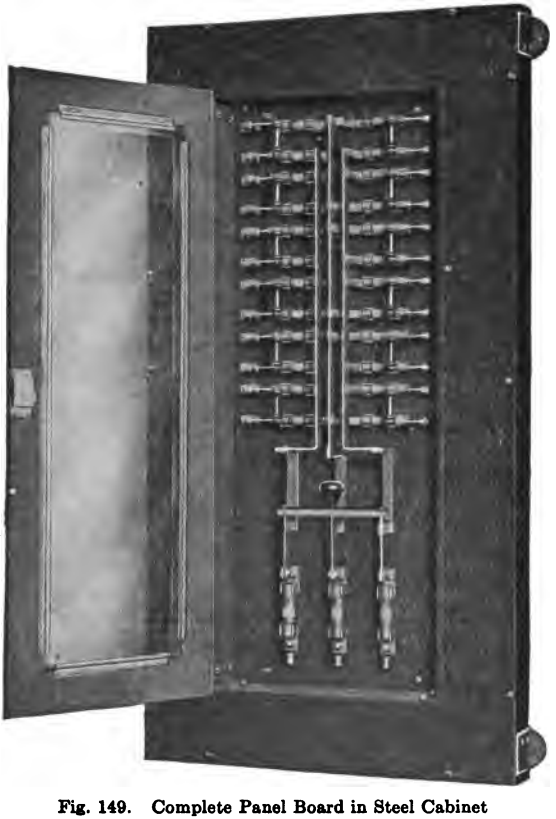


Fig. 149. Complete Panel Board in Steel Cabinet

are called Edison screw-shells into which the base of the incandescent lamp is screwed, the *shell* being connected in the socket to one of the lead wires and the *center contact* to the other lead wire. In all types the design of the socket or receptacle should be such that when a lamp is inserted there will be no current-carrying part of the lamp base exposed. This calls for a minimum depth of the socket of $\frac{1}{2}$ inch and sockets and receptacles which do not have such depth should not be used. Sockets and receptacles were formerly rated in candle-

power of the lamps designed for them or in amperes and volts but the introduction of the newer high-efficiency lamps such as the tungsten and nitrogen-filled lamps has rendered this method of rating inapplicable. All key or pull sockets and receptacles of standard types are now rated 250 watts 250 volts, or 660 watts 250 volts, with the added stipulation that this rating shall not be interpreted as permitting the use at any voltage of current above 2½ amperes, or 6 amperes, respectively.

Keyless sockets and receptacles of standard types are rated 660 watts, 250 volts, but not over 6 amperes at any voltage.

Miniature and candelabra sockets are rated 75 watts, 125 volts.

The new so-called "Mogul" sockets are rated at 1500 watts 250 volts and are for the larger sizes of lamps.

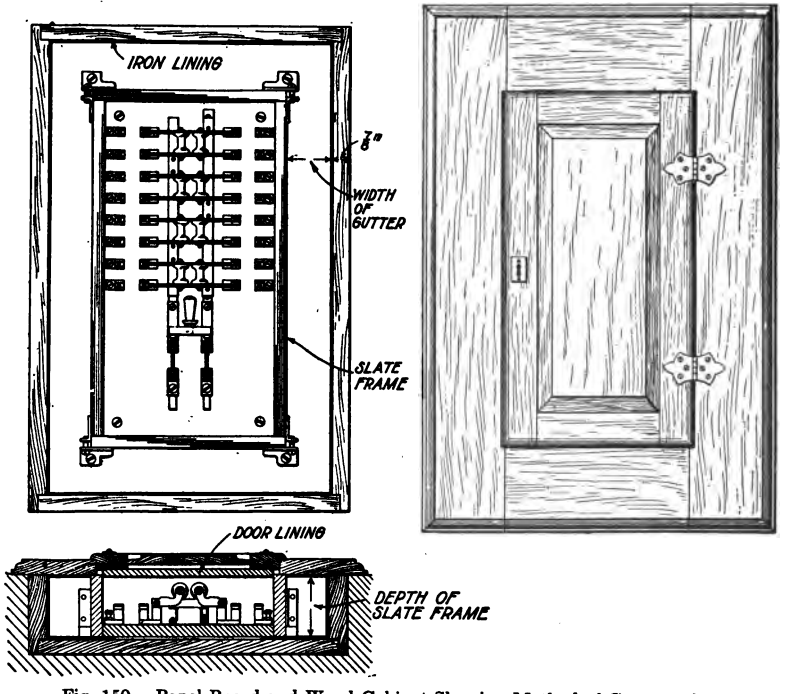


Fig. 150. Panel Board and Wood Cabinet Showing Method of Construction

Weatherproof sockets having no exposed current-carrying parts may be rated 660 watts, 600 volts, and thus may be used in series on 600-volt circuits.

The most common abuse of sockets is to employ them as outlets for currents far in excess of what they or the wiring immediately connected to them should carry and the above limits should be rigidly adhered to. The assigned ratings do not imply that the full power can be taken from each and every socket on a circuit at once. Thus twelve carbon 16 c. p. lamps in sockets may take 6 amperes on a 110-volt circuit and be fused with 6-ampere fuses. At 250 watts per socket, twelve sockets will take 3,000 watts which, at 110 volts, is over 27 amperes, an amount of power forbidden by the rules limiting lighting branch circuits to 660 watts and a current manifestly too large for the No. 14 wire which would usually be used on such a circuit. The ratings 250 watts, 250 volts, for key sockets, and 660 watts, 250 volts, for keyless sockets, are intended to express the maximum safe carrying capacity of each socket or receptacle alone and do not warrant employing them in the manner indicated above, which would seriously overload ordinary circuits.

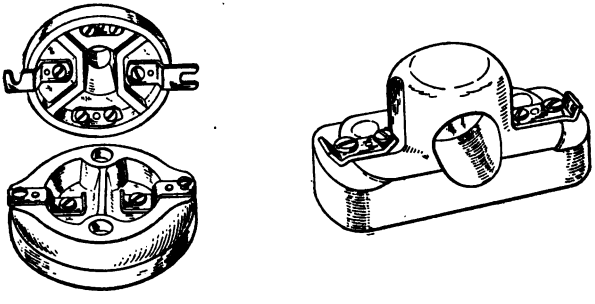


Fig. 151. Common Types of Fused and Unfused Rosettes

Rosettes. These devices are usually of porcelain and provide a means of connecting flexible cords to the main or branch circuits. Types are made either with or without small link fuses in the base but the unfused type is much to be preferred and should be used exclusively in general work since the use of link fuses in porcelain fittings is undesirable because of the possible results following a short-circuit blowing the fuses violently. It is much better to place all fuses at distribution centers, such as panel boards, and by keeping the fuses of proper capacity, depend on them for protection rather than on fuses scattered about in fittings, rosettes, etc. Fig. 151 shows common types of fused and unfused rosettes.

Bell-Ringing Transformers. Within the last few years small transformers have been brought out designed for the purpose of ringing door bells or for other light signaling work, deriving their power for such service directly from alternating-current lighting circuits in houses. They take the form of small, totally enclosed transformers with two very thoroughly insulated coils, the primary coil to be connected directly across an alternating circuit and the secondary to be connected to the bell circuit as shown in Fig. 152.

The push button is, of course, usually open so that no current flows over the bell circuit. When the button is pushed a current of low voltage (10 to 20 volts) and small ampere capacity (not over 2 amperes) flows over the secondary or bell circuit, the power being derived from the primary winding connected to the alternating-current line as in the case of any transformer. Absolutely no dependence can be put upon the insulation of the bell circuit which is often of cotton-covered paraffined wire (annunciator wire) installed in the most unreliable manner and the bells and push buttons are not designed for anything but very low voltage currents. It is,

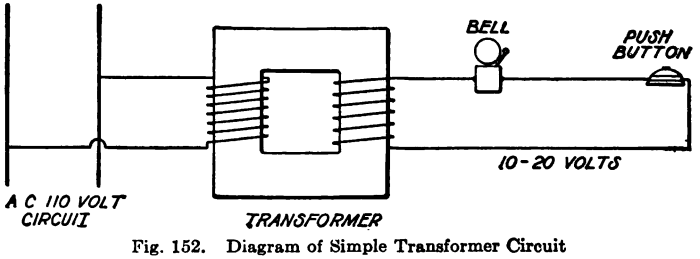


Fig. 152. Diagram of Simple Transformer Circuit

therefore, imperative that the design and construction and insulation of the transformer be such that under no conditions, either of service or from an accident, can the 110-volt current act directly on the bell circuit. Furthermore, the design of the transformer must be such that even if the push button be left closed or the bell wires become short-circuited only a very small current will flow over the bell wiring. In approved bell-ringing transformers both these results are secured with reasonable safety.

Heating Devices. The rapid introduction of all sorts of electric heating devices for domestic and industrial use has brought with it a special hazard which it is peculiarly difficult to control. These

devices are useful only as they are capable of developing a considerable heat in a short time. The normal use, of course, tends to draw away the heat and thus prevent a dangerously high temperature being reached, but if these devices are left connected to the circuit and unused, many of them will reach a dull red heat and may thus become a serious fire hazard. This is true of electric flatirons especially and also of many cooking utensils and other apparatus for domestic or light factory use. It is evident, therefore, that all such heating appliances should be made wholly of non-combustible material and, so far as their use will permit, be fitted with legs, guards, or other parts which will keep the heated parts well separated from walls, floors, tables, etc.

Stationary heating devices should be installed only when every precaution has been taken and the fact that perhaps only a low temperature will be produced by the proper and normal operation of the heater should not be made an excuse for omitting any of the precautions that would be taken for the higher temperatures which may easily result from accident or misuse. There should be ample air spaces and proper protection of adjacent surfaces by asbestos board and metal sheathing. In general all electric heating devices must be installed and used as possible sources of great heat.

Portable heating devices are not easily protected from misuse or accident. The chief protection against fires from such appliances appears to depend upon the original excellence of design and construction of the devices themselves, the fact that many of them employ but a small amount of energy, and, finally, upon a slowly growing appreciation by users and the public generally, that electrically-heated appliances, while usually fairly safe, if properly used, may very readily become dangerous if abused or improperly used.

Electric Gas Lighters. A battery, spark coil, and similar appliances are often used for the purpose of lighting the gas on gas fixtures without the use of matches. In such installations the wires from the battery and coil are led to the fixtures in any convenient manner and on the fixtures themselves small wires are carried down the outside of fixture stems and arms to the burners. The line wires are not insulated or installed in a manner comparable as to safety with electric light wires, and on the fixtures the insulation is especially weak and exposed to injury. It is, therefore, evident that such

gas-lighting systems should never be installed on the same fixture with electric lights, since a breakdown is very liable to permit the electric-light current to pass over the gas-lighting wires and cause a fire at some point perhaps concealed in a partition, either from overheating the small wires or from arcing to other wires or to grounded metal piping.

Marine Work. The Code contains special rules governing the installation of electric light and power wires and apparatus on shipboard. These differ from the standard rules in only a few particulars, as indicated by the need of special care to provide against the effects of constant and severe vibration, dampness and extreme hard usage to which marine installations are always subjected. The provisions of the Code should be referred to in detail by those who are called upon to install or inspect work of this special type.

REVIEW QUESTIONS

REVIEW QUESTIONS

ON THE SUBJECT OF

BUILDING SUPERINTENDENCE

PART I

1. What preparation and qualifications are essential to a superintendent of building operations?

2. What are batter boards, and how should they be prepared? What is a bench mark?

3. What is the advantage of laying a rough floor in buildings? Why is this often laid diagonally?

4. How much larger than the outside of the wall should the excavation of a cellar be carried? Why?

5. How far apart should laths be spaced? What defects warrant the rejection of laths?

6. What should the priming coat of paint consist of? How should knots be treated before priming?

7. What is the position of the architect, as superintendent, in relation to the owner and the contractor?

8. Describe the peppermint test for plumbing pipes.

9. Show by a sketch the difference between "block finish" and "mitered finish". What is a plinth block?

10. What must be considered in locating a dwelling?

11. What is a loose-joint butt? A loose-pin butt?

12. What should be the area of the cold-air box in relation to the piping to registers?

13. What particular points should be observed in the inspection of electric light wires?

14. How should the connection between lead and iron pipes be made?

15. What is the principal objection to the using of stock doors?

16. What makes a good finish for hard woods? What is the purpose of a "filler"?

REVIEW QUESTIONS

ON THE SUBJECT OF

BUILDING SUPERINTENDENCE

PART II

1. What is the usual arrangement in regard to use of party walls?

2. How is a cellar or vault wall usually protected from dampness? What material is to be preferred?

3. Describe the method of constructing brick-veneered buildings.

4. How is ashlar bonded, and what must be observed in backing stone with bricks?

5. What is meant by "half-slating"? Describe the appearance of good slates.

6. Describe five tools used in stone cutting.

7. What are some of the common defects to be noted in the inspection of cut stone?

8. What is a good proportion for cement concrete?

9. Give two formulas for the safe load on piling. What condition of moisture is necessary for the preservation of piling?

10. What is a rowlock arch? A gaged arch?

11. Describe the process of laying bricks. What common practice must be guarded against?

12. How are cast-iron columns tested? How should the ornamental caps be made?

13. What is broken ashlar? Make simple sketch.

14. Why are bricks wet, and how should it be done?

15. Upon what does the strength of a rubble wall mainly depend? What is coursed rubble?

REVIEW QUESTIONS

ON THE SUBJECT OF

UNDERWRITERS' REQUIREMENTS

PART I

1. Explain briefly the electrical causes of fires.

2. State in general terms the means to be taken in every installation to guard against such fires being started.

3. As affecting the fire hazard, describe the essential differences between

   (a) constant-current systems and constant-potential systems;

   (b) low-voltage and high-voltage circuits.

4. What is the National Electrical Code?

5. Into what main subdivisions are its rules divided?

6. Describe the chief desirable characteristics of a generating station with regard to the fire hazard.

7. In judging the safety of an installation of electric motors, what are the chief items to be considered?

8. Describe a motor-starting rheostat.

9. What is an autostarter?

10. What is the object of a continuous duty resistance?

11. What are transformers?

12. State the advantages of the use of transformers with regard to the fire hazard.

13. What precautions must be observed in installing transformers?

14. Outline the standard practice for outside wiring.

15. What is electrolysis?

REVIEW QUESTIONS

ON THE SUBJECT OF

UNDERWRITERS' REQUIREMENTS

PART II

1. What is open-work wiring?
2. What is the essential principle of conduit work?
3. What are the advantages and disadvantages of concealed work?
4. Outline the chief things to be considered in electric installations when subject to a continual dampness.
5. When should wood molding never be used?
6. What are the chief points to be observed in wiring a theater?
7. How should the footlights be installed?
8. With a voltmeter having a resistance of 24,000 ohms and a battery of 26 volts, it was found that the voltmeter read 6 volts when connected in series with the battery and the wiring of a house. What was the insulation resistance of the wiring?
9. Why are rubber-covered wires used almost exclusively in all inside wiring?
10. What is a "slow-burning" wire?
11. Describe a "weatherproof" wire.
12. Give the dimensions of a cartridge fuse for a circuit of 110 volts, 20 amperes.
13. In what way do telephone wires in a home affect the fire hazard and what fire precautions should be taken?
14. What is a snap switch and what is its distinguishing feature?
15. Describe a characteristic conduit installation for an apartment.

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